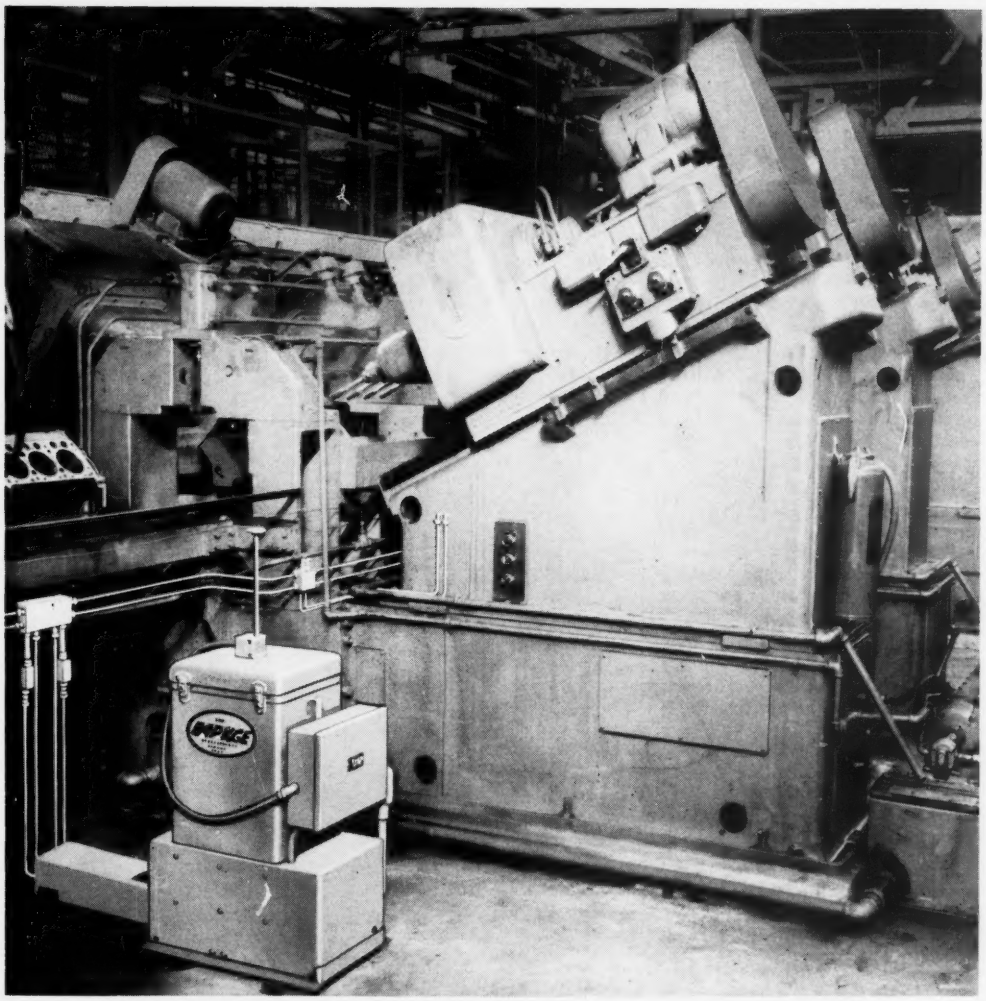
LUBRICATION ENGINEERING

DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE



Automation in Lubrication (see page 470)

JOURNAL OF THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS

Farval spray lubrication system keeps A-C ball mill running smoothly

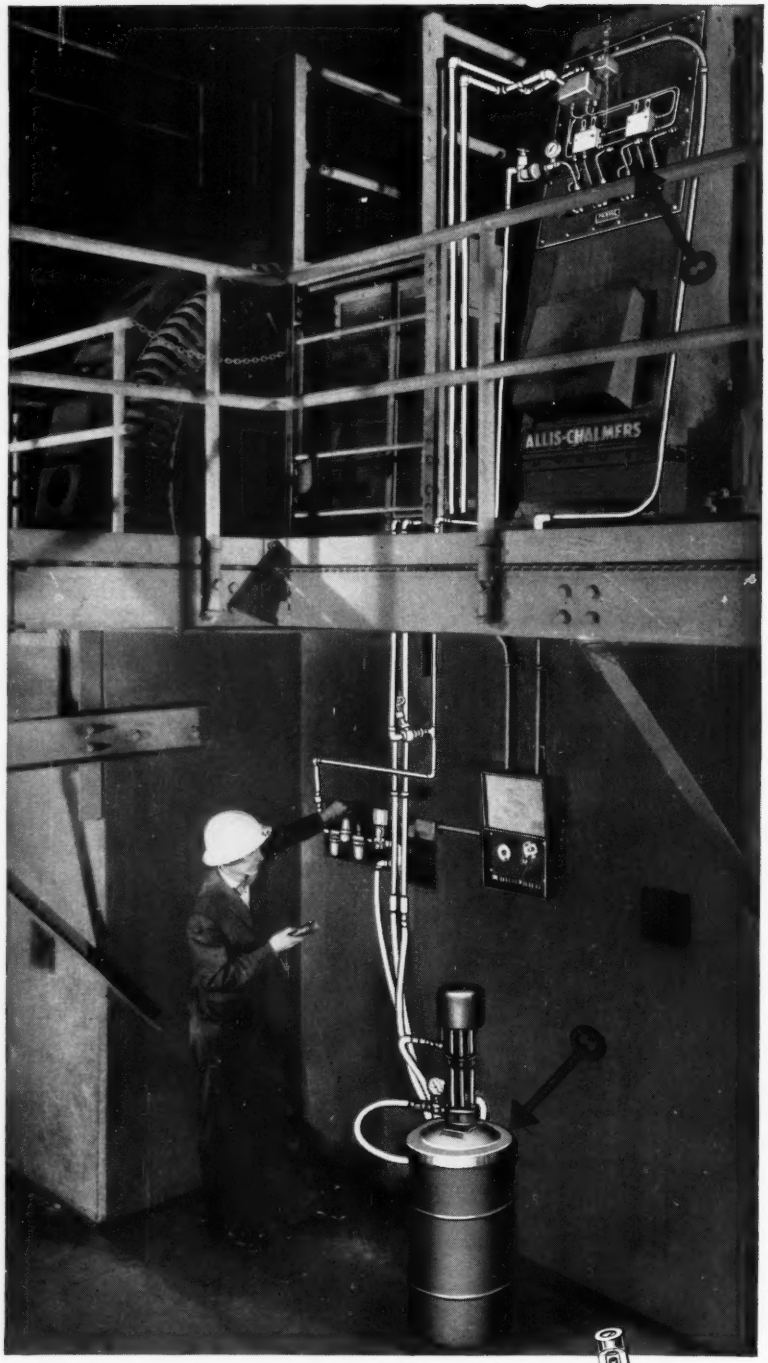
Inspecting the new installation of a Farval spray lubrication system on an Allis-Chalmers ball mill at Marquette Cement Company's Milwaukee plant is Erv Klovers, project engineer at Allis-Chalmers.

Mr. Klovers' task was to find an economical and dependable lubrication system to guard the large diameter, wide-faced gears that power the ball mill. So he contacted Farval and together we designed the original spray lubrication system for ball mill gearing. It was completely flexible in arrangement and position—fit his requirements to the letter—showed savings in both lubricant and labor costs.

With Farval, gears can be sprayed with the proper lubricant in any amount specified, as often as necessary—without waste or mess.

Hooked up to existing compressed air sources, Farval Spray Valves deliver the lubricant to tooth surfaces through controlled air delivery. Large porting in Farval Dualine valves ensure correct lubricant supply with minimum pressure-drop and very minimum grease separation.

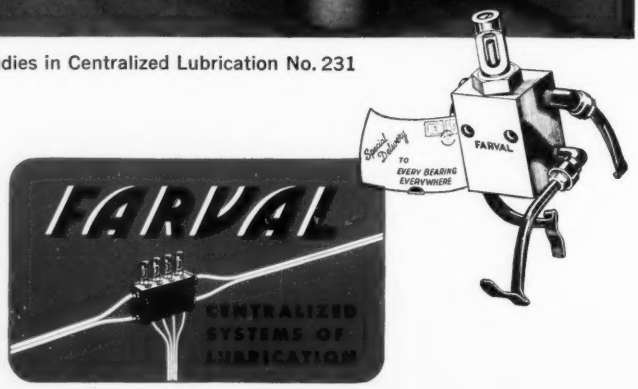
This simple, inexpensive but thorough lubrication system can help you cut maintenance costs as it has for hundreds of others across the nation. See what a Farval system can do for you by asking for Bulletin 26-S. Write The Farval Corporation, 3267 East 80th Street, Cleveland 4, Ohio.



FARVAL—Studies in Centralized Lubrication No. 231

KEYS TO ADEQUATE LUBRICATION

Wherever you see the sign of Farval —familiar valve manifolds, dual lubricant lines and central pumping station—you know a machine is being properly lubricated.



Affiliate of The Cleveland Worm & Gear Company, Industrial Worm Gearing. In Canada: Peacock Brothers Limited.

Volume 14, No. 11
November, 1958

Lubrication Engineering

DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE

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Cover photo courtesy The Farval Corp.

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Chemicals that Cool Refrigerators May Lubricate Aircraft and Missiles

A major problem in aircraft and missile development—lubrication at temperatures of 1,000 F and higher—may be solved with the same chemical that cools refrigerators, a government chemist indicated at the American Chemical Society's 134th national meeting.

Several gases of the Freon family, widely used as refrigerants, have been found to lubricate various metal alloys at temperatures up to 1,200 degrees Fahrenheit, reported Donald H. Buckley, a lubrication research engineer of the Lewis Fight Propulsion Laboratory, Cleveland, Ohio. The laboratory is directed by the National Advisory Committee for Aeronautics.

The gaseous lubricants function by combining chemically with the metal to be lubricated and forming a film that reduces friction; only certain gases will react with particular metals to create such a lubricating compound. Lubrication Engineer Buckley reported that certain nickel and cobalt alloys were effectively lubricated by the gases known chemically as dichlorodifluoromethane, dibromodifluoromethane and monobromotrifluoromethane. The speaker also reported that the presence of another gas, sulfur hexafluoride, in small amounts was "generally beneficial" to the formation of the lubricating film.

The Freon-12 was an effective lubricant for such iron materials as M-1 tool steel at lower temperatures, but the metal was corroded by the gas at temperatures above 600 degrees, according to the report, which was presented before the ACS Division of Petroleum Chemistry. In view of the corrosive action on iron, the researchers turned to the use of alloys based on nickel or cobalt.

The Freon gases were tried because they were known to be able to withstand temperatures as high as 1,000 F. When metals slide together, however, frictional heat may produce temperatures at the points of contact as much as 1,100 F above the surroundings. The lubricating gas decomposes at these local hot spots; and active atoms thus released react with the metal to form compounds capable of effective lubrication. Thus the lubricants are continuously reformed as needed.

Gases containing bromine atoms were found to be more effective with nickel alloys and the chlorine-containing gases were more effective with cobalt alloys.

"Optimum combinations gave friction coefficients (mathematical expression of the resistance to sliding) as low as 0.05 without excessive wear," Buckley reported. "An example of an effective combination is Stellite 98M2 (cobalt, chromium and tungsten) on Hastelloy C (nickel, iron and molybdenum) in monobromotrifluoromethane plus one percent sulfur hexafluoride at temperatures from 600 degrees to 1,200 degrees F."

The friction studies were made using a hemispherical rider, three-eighths of an inch in diameter, sliding in a circumferential path on the flat surface of a rotating disk two and one-half inches in diameter. A pressure of about two and one-half pounds was applied to the rider and the sliding velocity was 120 feet a minute. The apparatus was run in an atmosphere of the lubricating gas at temperatures ranging from 75 to 1,200 degrees Fahrenheit.

Robert L. Johnson, a mechanical engineer who is head of the lubrication section at the Lewis Flight Propulsion Laboratory, was coauthor of the report.

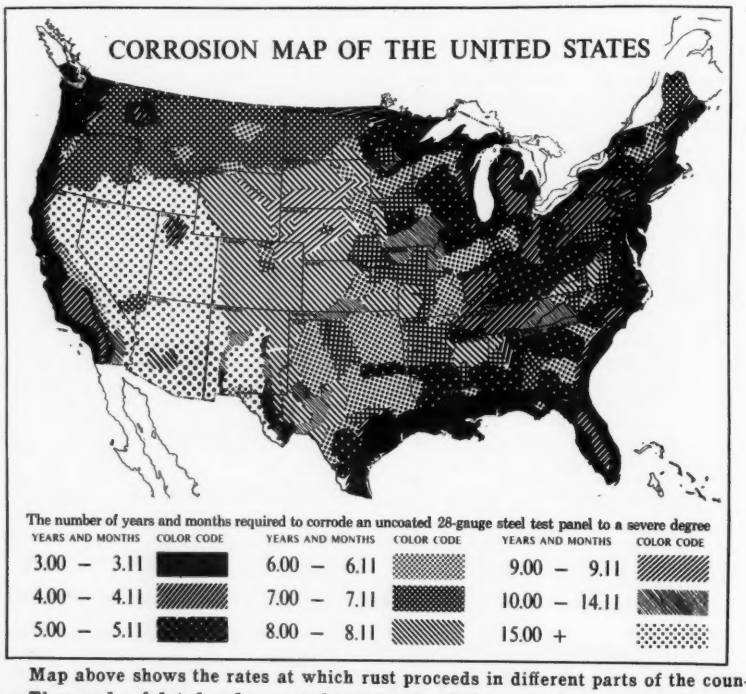
Study Compares U. S. Rust Rates

The comparative rates at which rust proceeds in different parts of the country have been established exactly for the first time for all United States cities over 10,000 population.

It takes three years, the fastest rate in the country, for rust to corrode a standard, uncoated steel test panel, the size of an auto license plate, in four different cities—Buffalo and Rochester, N. Y., Erie, Pa, and Miami, Fla. Slowest rust rate, more than 15 years, is in Tucson, Ariz., Roswell and Santa Fe, N. M. In all the nation's major industrial centers the rust rate is under four years.

This was disclosed in the first Rust Index of the United States, published by the Rust-Oleum Corporation of Evanston, Ill. The Index, the result of a 25-year research program, lists the 523 cities of the country with a population of more than 10,000 and the comparative rust rate for each city. Variations in rate result from the different amounts of rainfall, wind, corrosive gases, sunlight, and salt water present in each locality.

The rust rate is three years, one month in Pittsburgh; three years, two months in Los Angeles; three years, three months in Cleveland; three years, five months in Chicago; three years, six months in New York City; three years, eight months in Philadelphia and Detroit; three years, nine months in San Francisco; and three years, 10 months in Boston and St. Louis.


CORROSION MAP OF THE UNITED STATES
The number of years and months required to corrode an uncoated 28-gauge steel test panel to a severe degree
YEARS AND MONTHS
COLOR CODE
3.00 – 3.11
4.00 – 4.11
5.00 – 5.11
6.00 – 6.11
7.00 – 7.11
8.00 – 8.11
9.00 – 9.11
10.00 – 14.11
15.00 +

Map above shows the rates at which rust proceeds in different parts of the country. Thousands of dated and uncoated test panels of 28-gauge steel were left exposed at industrial sites throughout the country to establish the rate of rust in each locality.

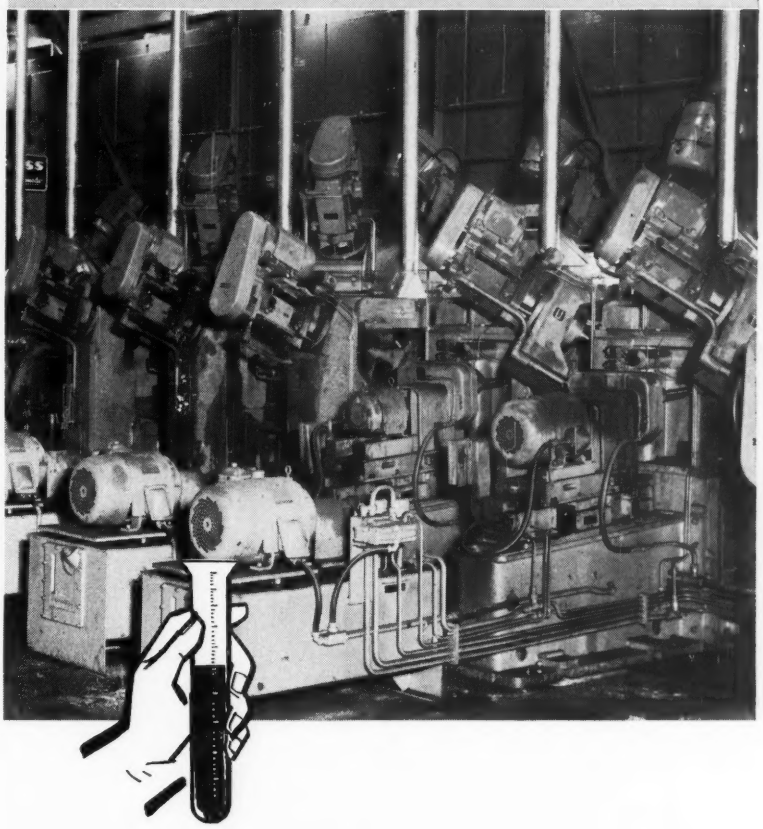
SECTION NEWS

Baltimore—Members at October 16 dinner meeting heard Norman R. Hostler, Tidewater Oil Co., discuss "Practical Application of Lubrication Greases." November 20 meeting will feature panel discussion of "Industrial Lubrication Problems as Viewed from Various Interests." The panel will be moderated by Charles R. Hand, Bethlehem Steel Co.; panelists are Warren C. Landis, Shell Oil Co., Robert B. McNutt, Garlock Packing Co., R. P. Staines, Davison Chemical Co., C. J. DeVries, Sexton & Peake, Inc. . . . **Boston**—October 20 session featured talk on "Recent Developments in Corrosion Control" by Dr. Herbert H. Uhlig of the Massachusetts Institute of Technology. . . . **Chicago**—W. H. Schrey, field lubrication engineer at National Tube Div. of U. S. Steel, spoke on "Evaluation and use of Fire Resistant Fluids" at October 16 dinner meeting. National Officers Night will take place on November 20 with ASLE President J. D. Lykins discussing steel mill lubrication. . . . **Houston**—Forty members and guests heard George Bane of R. G. Le Tourneau, Inc., speak on "Off-Shore Platform and Drilling Rig Lubrication." . . . **Hudson-Mohawk**—Industrial Lubrication Course jointly sponsored with Union College got underway October 7, will last until November 25. . . . **Kingsport**—Industrial Lubrication Conference under joint sponsorship of University of Tennessee takes place November 3 and 4 at Knoxville, Tenn. . . . **Los Angeles**—November 19 meeting will feature a discussion of electron computers in layman's language, "Electrons Can Calculate," by Joseph K. Slap, Alwac Computer Div., El-Tronics Inc. . . . **Milwaukee**—October 23 meeting was highlighted by panel discussion of "Preventive Maintenance" moderated by F. W. Johnson. Panelists were: Robert A. Guis, Standard Oil Co.,

(*Cont. on p. 491*)

The Philadelphia Section made its first presentation of the William P. Kuebler Memorial Award to Morrell E. Dougherty for his outstanding service and devotion in promoting the growth and success of the Philadelphia Section.

The Magic of Norgren MICRO-FOG Lubrication



1.6 fl. oz. of oil lubricates this huge machine 1 hour

The Micro-Fog Lubricator on this 80 ft. long machine lubricates 350 anti-friction bearings and 170 gears...a total of 750 bearing inches. Through the magic of Norgren Micro-Fog, just the right amount of fresh, clean oil is automatically and continuously applied to provide the best possible lubrication. Lubricant consumption is less than 1% of previous lubrication methods. Bearings run cooler. Bearing wear is minimized, reducing maintenance and replacement costs.

FOR COMPLETE INFORMATION call your nearby Norgren Representative listed in your telephone directory—OR WRITE FACTORY FOR BLUEPRINT MF-11

If it's Norgren...It's Dependable.

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Many Industries Represented At Lube Conference

Representatives of over 100 industrial organizations who attended the recent ASME-ASLE Joint Lubrication Conference came away with enthusiastic approval of the high-quality papers presented. Conference attendance records reflect considerable interest in the problems of lubrication since virtually every segment of American industry was represented. This fifth annual conference, sponsored jointly by the American Society of Lubrication Engineers and the Lubrication Division of the American Society of Mechanical Engineers, was held October 13, 14 and 15 at the Statler-Hilton Hotel in Los Angeles, Calif.

Six well-attended sessions were held during the three day conference. Two sessions were devoted entirely to basic studies of friction and wear, perhaps the most timely being those dealing with aircraft and missile accessory lubrication problems and the radiation resistance of lubricants. These latter subjects were especially interesting in view of the many new problems confronting the lubrication engineer in these fields. New developments in the field of nuclear power necessitate more exacting information regarding the changes in properties of lubricants exposed to electron radiation. A paper on this specific subject reported the effects of high energy radiation on turbine oil performance. Another paper on the development of seals for rocket engine turbopumps was of particular interest to the many representatives from the field of aircraft and missile accessory suppliers. (An order blank for preprints of these and other Joint Conference papers appears on page 492.)

Plans are now underway for the next Joint Lubrication Conference to be held at the Sheraton-McAlpin Hotel in New York, N. Y. on October 20, 21, and 22, 1959.

Oxygen Enrichment Speeds Cracking

Recently-concluded successful tests of oxygen enrichment for catalyst regeneration were conducted jointly by Linde Company, Division of Union Carbide Corporation and Cities Service Oil Company at the latter's refinery in East Chicago, Ind. From the data derived, it is calculated that feed-oil flow can be increased 15 per cent and standard conversion rate maintained. In effect, the oxygen addition increases the catalytic cracking capacity, and eliminates the need for capital expenditure by the refinery.

For some time, Linde has been investigating the possibilities of increasing production from catalytic cracking units through the use of oxygen enrichment of the catalyst regeneration air. A preliminary comparison of the possible production savings as opposed to oxygen costs showed promise of oxygen use being economical. Cities Service Oil Company had also been interested in this process, and co-operative arrangements were completed for a plant-scale test at the fluid catalytic cracking unit in East Chicago from July 28 to August 1.

In the Cities Service tests, oxygen enrichments up to 27 per cent by weight in the regeneration air were investigated, using oxygen additions of up to 150 tons per day rate. Most of the test data were collected using an oxygen enrichment of 100 tons per day, giving a final oxygen content in the regeneration air of 25.5 per cent by weight. Process control was smooth and uniform over the entire range of enrichment. Coke burning capacity of the regenerator increased in proportion to the additional oxygen available for combustion. Temperature control, oxygen utilization (pounds of oxygen per pound of coke burned), oxygen content in the flue gas, and residual coke on the regenerated catalyst did not change appreciably from normal operating conditions encountered with air. A trend toward improvement in operating performance was indicated when using the higher oxygen concentrations. The net effect of adding 100 tons per day of oxygen was to increase the conversion of feed oil by approximately 5 per cent by volume at constant feed rate, or to increase the feed rate by 15 per cent by weight at constant conversion.

Scientists Find Straight Mineral Oil Adds to Gear Load-Carrying Capacity

A new discovery may have an important effect upon the design of missile lubrication systems.

Southwest Research Institute announced a decided gain in the ability of lubricants to provide lubrication for high-speed gears in an atmosphere from which air has been removed. This finding was made in a research program on the lubrication requirements of missiles and space vehicles conducted at SwRI under Air Force sponsorship.

It was found that a straight mineral oil, as well as the same mineral oil fortified with three different "extreme pressure" additives, all exhibited decided increases in "gear load-carrying capacity" when the gears were operated in an atmosphere filled with nitrogen or argon, instead of air. The three extreme pressure additives used represent, respectively, a phosphorous type, a sulphur type and a chlorine type additive. The results obtained to date show that with the air removed from the system, the load-carrying capacity was approximately doubled. Whether this same effect applies to other types of lubricants is not yet known. Work is now in progress to study this effect on typical synthetic lubricants.

Increased load-carrying capacity is important because of the necessity of keeping gear weight at a minimum. Consequently, the gears must operate at the highest permissible loads, speeds and temperatures. In aviation gas turbine engines, gear weight accounts for almost one-fourth of the total weight of the power plant. Although no figures can be quoted, the problem of providing adequate lubrication to missile power plants is far more acute. The removal of air or saturation of the lubrication space with an inert gas such as nitrogen appears to offer a very attractive solution.

SwRI has been working for the past six years on a comprehensive program of research on Air Force lubrication problems associated with aviation gas turbine and jet engines. As a result of this effort, nearly every U. S. military specification for current or advanced types of aviation gas turbine or jet engine lubricants contains some test method either devised or perfected by SwRI.

With the advent of the Sputnik, the Air Force research program at SwRI was quietly converted to meet the problems of the missile age. Although the full details of the program cannot be revealed, the scope of the work is suggested by the fact that the lubrication requirements of gears and bearings at very high speeds, high temperatures, and simulated high altitudes are under close scrutiny, as are the foaming characteristics of liquid lubricants at high temperatures and simulated high altitudes.

The Air Force missile lubrication program is under contract AF 33 (616)—3820. This project is monitored by the Propulsion Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, with H. R. Smith and G. A. Beane as project engineers.

Tolerances .0002 with Cities Service Cutting Oil!

If you think the days of the precise craftsman are a thing of the past, you ought to take a tour through Arch Gear Works at North Quincy, Massachusetts.

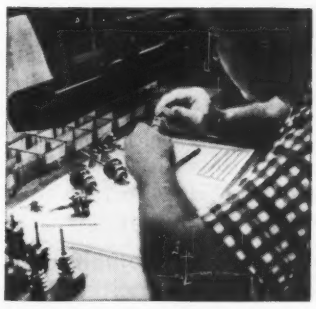
There, you'd see some of the nation's foremost specialists in precision gearing going about their jobs with the most painstaking accuracy.

Such accuracy is absolutely vital at Arch Gear Works, because this unusual firm produces amazingly intricate mechanisms involving as many as 50 tiny precision gears... gears that automatically control the speed and torque of sensitive electro-mechanical devices.

In this highly complex, precise operation, Cities Service is the choice of cutting oils for a very simple reason: Cities Service Cutting Oils deliver .0002 tolerances and the finest possible finish. Few oils can match this performance.

With equally outstanding results, Arch Gear Works uses Cities Service Anti-Corrode to protect its gears during shipment, and Cities Service Pacemaker Oils for general lubrication and hydraulic machinery.

But you needn't operate a gear works to prove that Cities Service lubricants are geared to *your* operation. Simply talk with a Cities Service Lubrication Engineer. Or write: Cities Service Oil Company, Sixty Wall Tower, New York 5, N.Y.



Specialist Assembles Tiny Gear. Some mechanisms contain as many as 50 tiny precision gears—all produced with the aid of Cities Service Cutting Oils—and protected during shipment by Cities Service Anti-Corrode.

CITIES SERVICE

QUALITY PETROLEUM PRODUCTS

KEEPS CUTTING FLUIDS
AS FRESH AS A DAISY

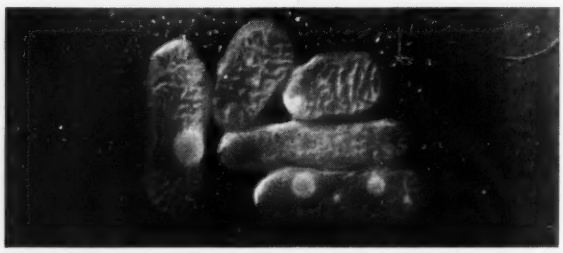
Here's why ELCIDE 75™ can increase the useful life of your soluble oil emulsions

Elcide 75 controls harmful bacteria that enter all oil-water emulsions and cause rancid odor, acidic corrosion, and emulsion breakdown. Prior to the development of Elcide 75, certain bacteria developed immunity to commonly used germicides, and no single inhibitor could control their damage.

Elcide 75 is a combination of proven anti-bacterial agents, including one of the safest and most powerful bacterial inhibitors used in the exacting field of medical surgery today.

Elcide 75 is not a "built-in additive" that is weakened by larger emulsion ratios. With Elcide 75 you know you have an effective, safe treatment because you add it to the emulsion right in your own plant.

Elcide 75 is completely safe for employees, machinery, and products. Not only is it non-toxic and harmless to sensitive skin, but its anti-bacterial action reduces the chance for infection caused by contaminated emulsions. The use of Elcide 75 also reduces the acidic corrosion caused by bacterial decomposition.



Bacteria cause emulsion trouble. This is a photomicrograph of *Pseudomonads*, one of the harmful types of bacteria found in oil-water emulsions. They enter the emulsion through the air, water, and plant debris, and make it possible for sulfate-reducing bacteria to cause odor, corrosion, and emulsion breakdown. Elcide 75 controls a much wider range of these and other types of damaging bacteria.

WHAT ELCIDE 75 MEANS TO THE METALWORKING INDUSTRY...

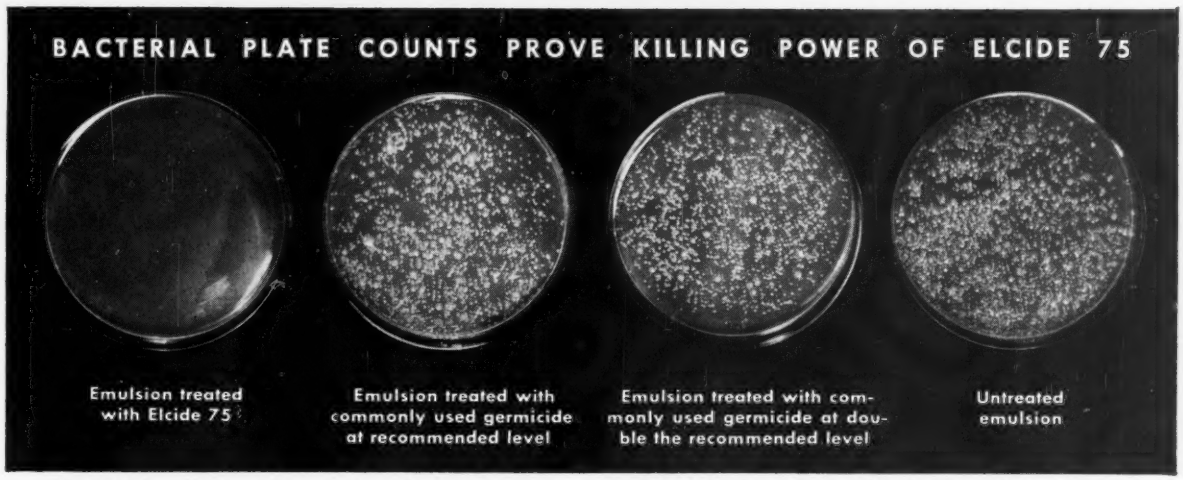
Operating costs can be greatly reduced because of Elcide 75. This saving is an accumulation of several important benefits.

Actual shop tests have shown that one ounce of Elcide 75 added to each four gallons of emulsion can keep the oil-water emulsion fresh as much as 5½ times longer. In one test, emulsions that normally had to be dumped at the end of four weeks ran for 22 weeks when treated with Elcide 75!

You can benefit by three direct savings—costly labor and down time for recharging will be reduced, your soluble oil requirements will drop, and the disposal cost of spoiled emulsions will diminish.

Elcide 75 also contributes to better products and longer machine tool life because it controls the bacteria which often cause acidic corrosion.

You can have a cleaner plant by using Elcide 75. It eliminates objectionable odors as well as bacteria that may cause skin infection. Elcide 75 is nontoxic and safe to use, as proved by tests conducted under normal shop conditions.


BACTERIAL PLATE COUNTS PROVE KILLING POWER OF ELCIDE 75
Emulsion treated with Elcide 75
Emulsion treated with commonly used germicide at recommended level
Emulsion treated with commonly used germicide at double the recommended level
Untreated emulsion

The photographs shown above illustrate the broad, powerful anti-bacterial action of Elcide 75. The light areas are bacterial colonies that have grown in three of the emulsion samples during 8 weeks' use. Note that none of these harmful bacteria appear in the emulsion treated with Elcide 75 during the same 8-week period. The emulsion stayed fresh.

PUT ELCIDE 75 TO WORK FOR YOU

The best way to determine the value of Elcide 75 to your own operation is to try it under normal plant conditions, using your regular oil-water emulsion. After you compare the costs of operation, you will agree that Elcide 75 is a valuable discovery that deserves a permanent place in your plant. Why not try Elcide 75 soon?

ELCIDE 75™
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Lilly

PRODUCT SPECIFICATIONS
ELCIDE 75

(Lilly's brand of bacterial inhibitor for cutting fluids)

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1-gallon polyethylene	$8.50
5-gallon polyethylene	$8.00
55-gallon stainless steel	$6.50

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TELEPHONE: MElrose 6-2211

Cutting Fluids Increase Efficiency

How cutting fluids can improve the efficiency and economy of machine tool operations is being demonstrated at the Milford, Connecticut plant of U. S. Electrical Motors, Inc.

Until recently, the plant used a conventional soluble cutting oil, mixed in a 10-to-1 (water-to-oil) ratio, on a Milwaukee milling machine that cuts keyways in shafts for various models of motors made by the company.

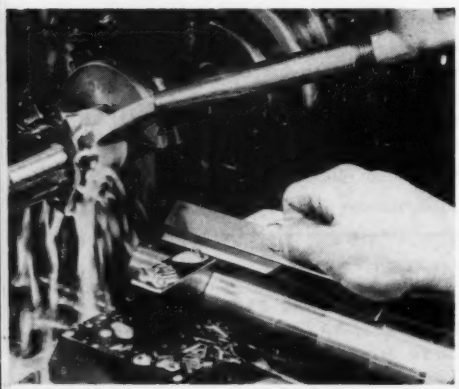
By switching to a heavy duty soluble cutting oil, developed by Gulf Oil Corporation, the plant realized several advantages of economy and machine tool performance. The heavy duty soluble oil can be mixed with water in a 35-to-1 ratio, instead of 10-to-1. Service life of this mixture is three months in contrast with three weeks that the conventional oil lasted before it had to be changed.

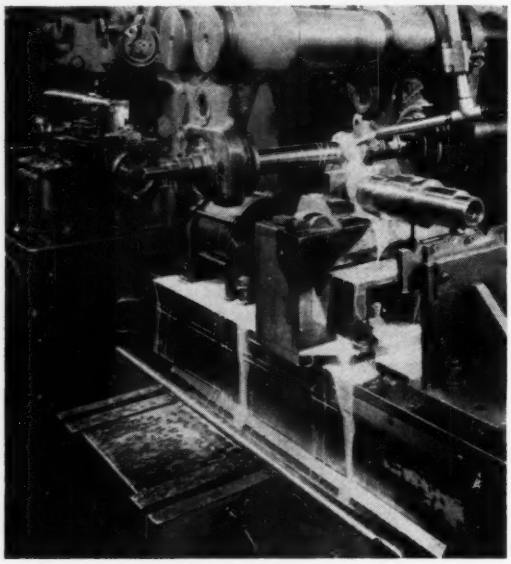
The better cooling properties of the 35-to-1 mixture of Gulfcut Heavy Duty Soluble Oil have doubled tool life on the milling machine, according to U. S. Motors production personnel.

A thin, but extremely durable, anti-weld film formed by this oil between the tool and the chip permits holding closer tolerances on critical cutting jobs. Tolerances for the keyway cuts are being held with much greater consistency than previously.

Oil splashes on machinery and personnel have been reduced because the heavy duty grade cutting oil contains a non-foaming agent that prevents excessive frothing. This feature also lets the oil flow more freely to and from the work.

Closeup of shaft keyway cutting job setup on Milwaukee milling machine at U. S. Electrical Motors, Inc., Milford, Connecticut.





Use of heavy duty soluble cutting oil for this Milwaukee milling machine cutting keyways in take-off shafts of gear units at the U. S. Electrical Motors, Inc., plant, Milford, Connecticut, has doubled tool life and improved tolerances. Gulfcut Heavy Duty Soluble oil is mixed in a 35-to-1 water-to-oil ratio and it lasts three months, compared with a three-week service life of a 10-to-1 mixture of soluble oil previously used. The heavy duty mixture contains a non-foaming agent that prevents frothing and splashing.

Numerous other difficult machining operations are performed throughout this plant during the manufacture of U. S. Electrical Motors line of Syncrogear, Varidrive, Uninclosed, and others types of industrial motors.

One of the toughest is the deep hole drilling of hollow shafts for motors. In this operation, the plant uses a dual-spindle Pratt & Whitney machine that simultaneously drills two shafts having hole diameters ranging from 11/32-inch to 1-9/16-inch. Shafts vary up to 25-9/16 inches in length.

Principal problem in the operation is heat. Experience by the plant has proved that Gulfcut 41C, a sulfo-chlorinated fatty oil, has the required properties to cool the work, save the cutting edges of the tool and remove chips. The oil is delivered to the cutting edge at a pressure of 200 lbs. per square inch. Forty gallons of oil per minute circulate through the system.

Tolerances and surface finishes are reported to be substantially better than those called for in specifications. In one case, 1045 hot rolled steel is being drilled 7/8-inch per minute at a surface speed of 350 feet per minute with a 1-9/16 drill. The inside diameter of the hole is being held within .002 of the drill size. Surface finish obtained is 45/50 micro-inch. Speed of each spindle on the machine is controlled by a U. S. Motors Varidrive motor equipped with a brake that stops the spindle instantly after the hole is drilled.

Lubrication is a vital factor in the operation of three high production 150-ton stamping presses at the U. S. Electrical Motors plant. Bearing failure in these large machines would mean expensive lost time for replacement. Central lubricating systems force-feed Gulf Harmony 97 oil to all important parts of the presses. This is a non-corrosive lubricant that is inhibited against oxidation.

The three large heavy duty presses pierce rotor laminations for U. S. motors. Blanks are fed automatically by a hydraulic magazine which uses Gulf's Harmony 53 as the hydraulic medium.

To keep the multiple-punch, piercing dies sharp, the 26 gauge silicon steel blanks are coated with Gulfcut 11A before the operation. This is a non-staining, non-corrosive mineral lard oil, giving excellent protection and long life to the tools, which are subjected to the extreme abrasive action of the silicon steel. Because of its non-staining characteristics, it is also an excellent oil for use on non-ferrous metals.

Successful performance of Gulfway 52 on the ways of a heavy duty horizontal boring machine has led the U. S. Electrical Motors plant to select this way lubricant for all machines in the shop. If the way lubricant on the horizontal boring machine gummed or otherwise deteriorated, it might result in misalignment of the main spindle which, in turn, could affect tolerances of the stator frames being bored, faced and registered. The relatively thin film of way lubricant must withstand high pressures in this machine.

in'dis·pen'sa·ble
is the word to describe

"A Survey of Journal Bearing Literature"

Compiled and written by Professor Dudley D. Fuller, recognized authority in the field of bearing design and lubrication, Mechanical Engineering Department, Columbia University and Principal Scientist, Franklin Institute Laboratories for Research and Development.

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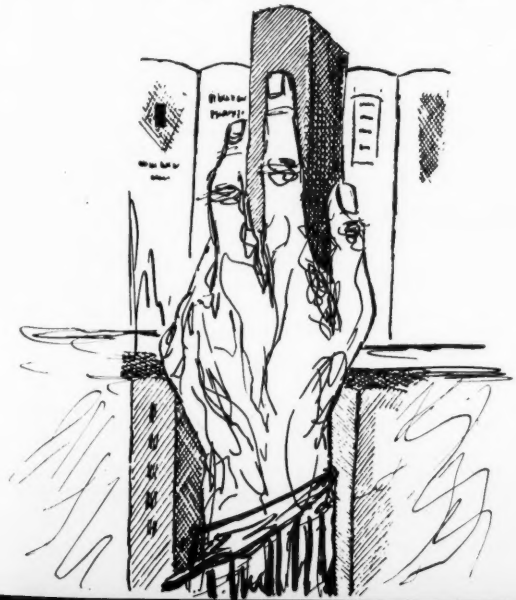

American Society of Lubrication Engineers
Department SU-11
84 East Randolph Street
Chicago 1, Illinois

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ALBERT SAUVEUR *was the first man in America to study steel through a microscope. In that way he noted the relative effects of temperature, amount of work, cooling rate and chemical composition on the grain size of both rolled and forged steels.*

From these studies, Dr. Sauveur was able to show that there was a certain critical temperature which, following hot work and slow cooling, yielded the smallest grain size. This brought immediate modifications in rolling and forging procedures which, until then, had been done at the highest possible heat.

Thus, in 1896, began researches into the working and heat treatment of steel which form the basis of our present knowledge of metallurgy. In almost every branch of this science, Albert Sauveur contributed useful and important knowledge. Harvard University describes him as "a founder of the science of metallography". For this, and his life's work as scientist, teacher and our first consulting metallurgist, his is a great name among steel makers.

Great Names in Steel Making

The same day Albert Sauveur first focused his microscope on a specimen of steel, a mill employee on the Monongahela was busy paddling heavy grease on the roll necks of a small hand mill. The grease, a fatty base material having a high melting point, had recently been compounded by The Ironsides Company, of Columbus, Ohio. It was called "Shield" and performed so well that the name "Shield" in time, became synonymous with satisfactory lubricants.

The work of steel makers and lubrication engineers has come a long way since then — from small, slow mills, greased by hand with a paddle, to today's four and five stand continuous mills requiring automatically applied lubricants able to support sustained mill speeds of 4300 fpm and pressures as high as 25,000 psi.

In this progress, Ironsides specialists have "teamed" with mill superintendents, lubrication engineers and rollers to solve numerous problems. To achieve a satisfactory roller bearing Shield, for example, it was necessary to develop a pumpable, water repellent, extreme pressure lubricant that was also free-running in order to minimize the enormous power consumption of modern rolling mills. The even tougher problem of producing a domestic roll oil to replace imported palm oil was licked by the development of Palmoshield.

Ironsides engineers are equally accustomed to studying the problems of individual mills and compounding lubricants for specific conditions and preferences. These "custom tailored" lubricants are supplied in any quantity, from pails to tank cars.

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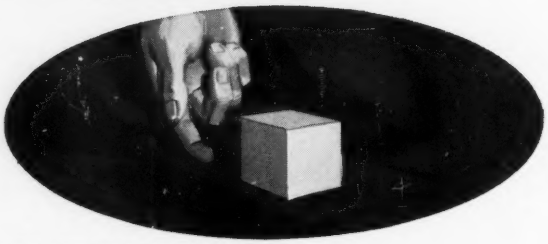
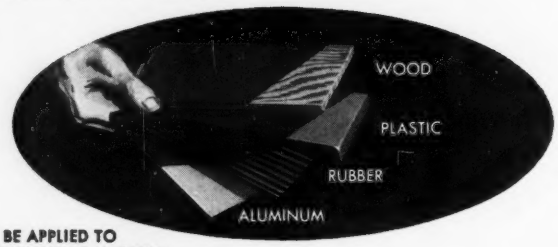
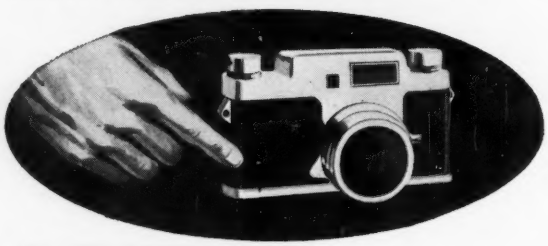


LOW COEFFICIENT OF FRICTION



MAY BE APPLIED TO HEAT-SENSITIVE MATERIAL



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NEW PRODUCTS

HYDRAULIC POWER CHECK PROVIDES PRECISE FEED

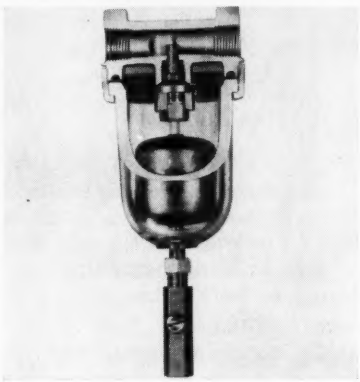
A new in-line single-acting hydraulic power check, designed to provide precise feed control of air cylinders and a variety of other machine feed components, has been introduced by the Appco Corporation. The new model will check thrust loads up to 1500 lb and provides checking action on either the forward stroke or the reverse stroke, and unrestricted movement on the opposite stroke. When applied to pneumatic cylinders, it prevents chatter and flutter, and provides uniform feed that is unaffected by variations in power thrust. The self-contained unit consists of an oil-filled spring loaded cylinder, checking piston and piston rod, and extra sensitive needle valve control, and is installed by attaching the cylinder to a fixed portion of the machine and piston rod to the member to be controlled. Any portion of the piston rod forward stroke can be controlled by positioning the adjusting nuts and locknuts on the rod at a predetermined distance on opposite sides of an activating bracket. The forward stroke is unrestricted until the adjusting nut on the rod contacts the activating bracket, the remainder of the forward stroke is controlled. The distance of travel is determined by the positioning of the stop nuts in relation to the bracket while the speed is controlled by an external adjusting screw. This unit is available in six sizes with strokes from two to twelve inches. Overall collapsed lengths range from 18¼ to 26¼ in. Cylinder bore is 1.385 in. on all models and piston rod diameter ½ in. The Appco hydraulic check features one piece construction of the checking cylinder heads. All piston and head seals are equipped with standard "O" rings. The cylinder bore is precision honed to eliminate internal leakage and the piston rod is hard chromed to resist wear. Mounting devices permit mounting the cylinder in any position. All AN and JIC specifications are met or exceeded. For further information on the model 1500 Appco hydraulic check, write Appco Corp., P. O. Box 6, Olmsted Falls, Cleveland, Ohio.

HYDRAULIC FILTER

A new line type hydraulic filter has been developed by Capital Engineering & Mfg. Corp. for filtering of all types of hydraulic fluids, lubricants, fire-resistant liquids and coolants. The filter is smaller in size than others of equal filtering capacity, making its use reportedly possible in restricted spaces where others cannot fit. The filtering element is made from Monel wire mesh in small corrugations with Monel support with top and bottom of Monel metal. This element is fitted into a housing of aluminum alloy and is recommended for pressure of 175 psi. It is quickly and easily disassembled for easy cleaning and re-assembled in a minimum of time. For further information write Capital Engineering & Mfg. Corporation, 5837 S. Ashland Ave., Chicago 36, Ill.

AUTOMATIC FILLING SYSTEM

An automatic filling lubricator manufactured in pipe line sizes of ¼ in. to 1 in. is claimed to maintain a constant maxi-



mum-minimum oil level in the lubricators alone or in combination with airline filters and regulators. The lubricant is supplied by pipe line direct from 55 gallon drums at a central pumping station to any number of lubricators in operation. It is said to eliminate the usual hand filling or manual servicing problems which stop production. Hand fill lubricators previously installed and in production can be easily and economically converted to the automatic filling system. Bulletin ALS-602, will be furnished on request from Arrow Tools, Inc., 1923 S. Kostner Ave., Chicago 23, Ill.

FILTER CARTRIDGE

Positive filtration in the micronic range —conservatively rated for removal of particles .0015 inches (40 micron) in size—is now available with a new all-metal, edge-type filter cartridge, designed and produced by the Cuno Engineering Corporation of Meriden, Connecticut. Especially adaptable for lubrication, hydraulic and fuel applications, the new filter assures a fine degree of filtration plus high flow capacity. A typical filter, measuring only 4 inches face to face, handles in excess of 7½ GPM of 50 SSU fluid at 2 psi drop. The compact, cleanable all-steel cartridge is designed to fit a wide range of standard housings.

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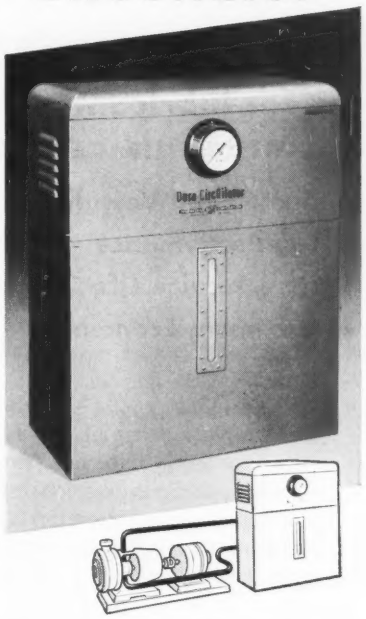

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HIGH EFFICIENCY — Advanced design, double-acting **mechanisms** assure dependable low surge operation with minimum air consumption. Large **air passages** allow unrestricted venting.

PRECISION MADE — All mating surfaces of plunger, Bushing and Air Valve are microlapped to high tolerance ... prevents by-passing lubricant or bleeding off air. No washers or packings to replace.

SIMPLIFIED MAINTENANCE — Modular design of **Pump Tubes** provides extreme ease of disassembly ... invaluable when using compounds which may "set up," such as paints, plastics, etc. Entire mechanism can be assembled only "hand tight" and function perfectly for an indefinite period. **Air Motor Piston** and **Cylinder** ... No oiling required ... minimum friction ... no leather cups.

LIGHT WEIGHT — Generous use of aluminum makes **Pump** amazingly light in weight and distributes heat to prevent "icing" of **Air Valve.**

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LINCOLN ENGINEERING COMPANY
Division of The McNeil Machine & Engineering Co.

Lube Lines

by A. F. Brewer*

No Place for Calculated Risk

In certain phases of business the calculated risk is an acceptable factor. This also holds true in production. Wherever goods are being manufactured for sale, there must be some calculated risk when the market is being surveyed. One cannot always predict customer acceptance, competition, or the vagaries of human nature. In packaging, color has sales appeal to some, but remember, a lot of prospective customers may be color blind.

In lubrication, however, there should never be any calculated risk. And yet, too many of us in the routine maintenance of our home appliances, even our cars, subconsciously assume a calculated risk. The builders' instruction manuals tell us when and how to lubricate, but how many of us follow these manuals? Or, if we do, how much attention do we pay to the type of lubricant which should be used? Too often, "anything goes," until a motor overhaul job is required because of a clogged oil filter or stuck rings, or because the power mower bearings react unfavorably due to sand and dirt accumulation. Fortunately, correction usually is not too costly and can serve well as an object lesson. Next time follow the book.

The thought cannot be passed off so easily, however, where high priced industrial production or power plant machinery is involved. Here, there is the insurance value of lubrication to be considered. This is a three-fold value as it includes continuity in machine operation, low cost maintenance and reduction in production costs. Certain operating ranges will indicate why this insurance value has such a vital relationship to the ultimate decision which management must make as to how much their product can be sold for, viz: profit or loss.

We can consider these so-called operating statistics according to speed, temperature and pressure.

The service will influence the most effectual speed range. What would be high for one machine would be slow for another. The problem of lubrication very often will vary directly with the speed, although the operating temperature must not be overlooked. Where high speed grinding is involved with the wheel turning around 60,000 rpm. the temperature generated by an unsuitable grade of lubricant could adversely affect the running clearance and, as a result, might damage the surface finish. Obviously, introducing a calculated risk because "any available" machine oil is good enough, could be hazardous.

Just as a wide-speed range prevails in modern production machinery, a wide temperature range also prevails. From —60F in refrigeration to around +2000F in glass making or certain metal industries are conservative figures. Sometimes the lubricant must be exposed to these temperatures. Many types of lubricants just cannot take it. For example "any available" machine oil might congeal at temperatures not too far below zero and lose virtually any vestige of its lubricating value above around 400F. To eliminate the calculated risk the lubricant must be prepared, selected and applied with due consideration of the operating temperature to which it must be subjected.

Pressure is of concern because it may be quite a variable. Pressure exerted upon a bearing or gear tooth surface depends upon the load. Where this is continuous, there is less chance of metal fatigue than where periodic shock loading occurs. Consider for example, the load imposed upon the bearings of a metal press or forging machine. On the other hand, where rotary motion prevails as with a turbine, the bearing pressure is more uniform. In view of the trend to design for higher pressures it is obvious that the useful life and productive ability of a machine will depend upon the protection afforded by lubrication. The chemist has developed certain additive materials which increase the load-carrying ability of certain basic types of lubricants. The lubrication engineer has proved the worth and adaptability of these compounds. We have progressed beyond the calculated risk stage in the application of extreme pressure lubrication. When it is studied with respect to the operating speed and temperature, the additional cost is returned many-fold.

Calculated risk in lubrication is more apt to be prevalent in a plant where ill-advised economy policies are practiced than in the plant where the operating personnel are cognizant of the troubles and headaches which can result from "thoughtless" lubrication. When the lubrication engineer has established a logical plan for maintenance of lubrication, the people who run the machines know that they will benefit by following this plan. But when someone up front pinches pennies and figures something cheaper is just as good, then the chickens of calculated risk are much more apt to come home to roost.

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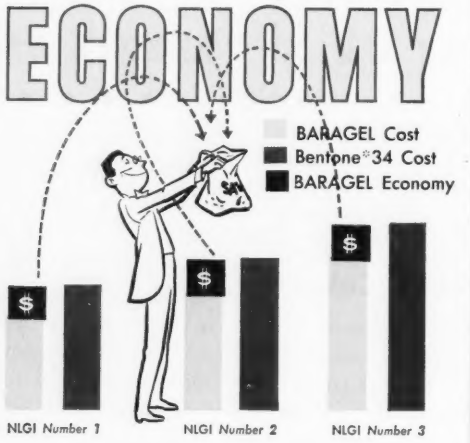

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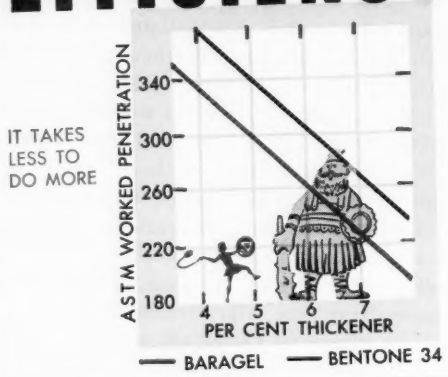

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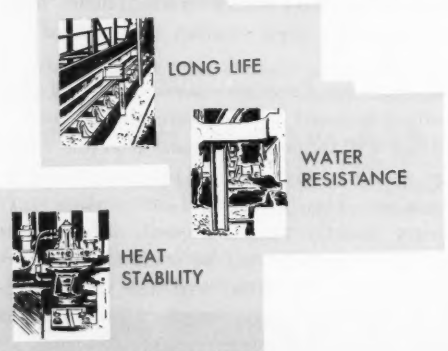


Vol. 14, No. 11

Lubrication Engineering

you gain through membership gains

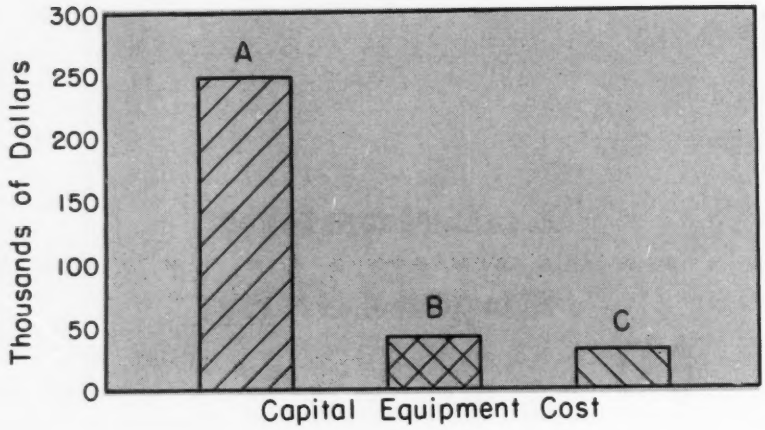
Every year at about this time, the various ASLE sections begin their membership drives. There's a lot of talk about getting new members, of having educational courses, of replacing members who dropped out during the past year.

Perhaps this is the time of year when some of us become sleek and complacent—we look back on last year with no little pride in our accomplishments, and we figure that this year can take care of itself. True, last year was a good year—it marked the first issue of ASLE *Transactions,* it saw "The Survey of Journal Bearing Literature" put into print, it continued the ever-increasing recognition of the lubrication engineer and his work.

But before we become too pleased with our accomplishments, it's always a good idea to look at what remains to be accomplished. There is still a great deal that must be done in order to gain the proper recognition for lubrication as a science—as a highly specialized endeavor. To effect this, we must have funds for research and for education. These funds will become available only through increased membership and through increased industrial awareness of the importance of the lubrication engineer's function.

Each individual member stands to gain greatly from an expansion of the Society. And each individual member can bring about such a gain by bringing one new member into the Society. Bring a guest to your section meeting, and follow up his visit with your own sales talk on what both he and you stand to gain from his membership.

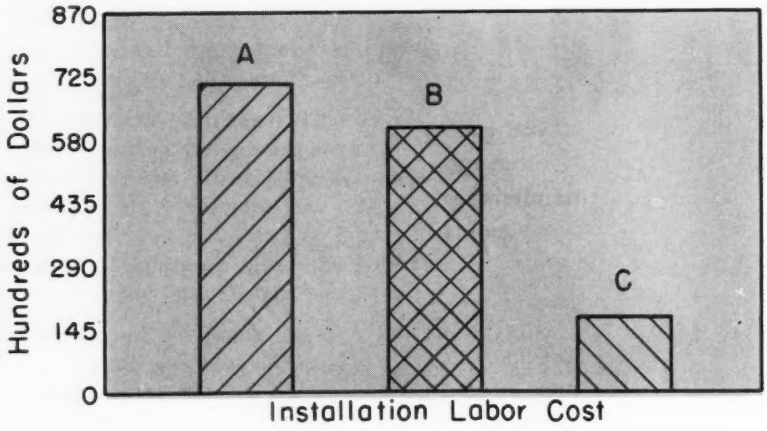
J. D. Lykins, President

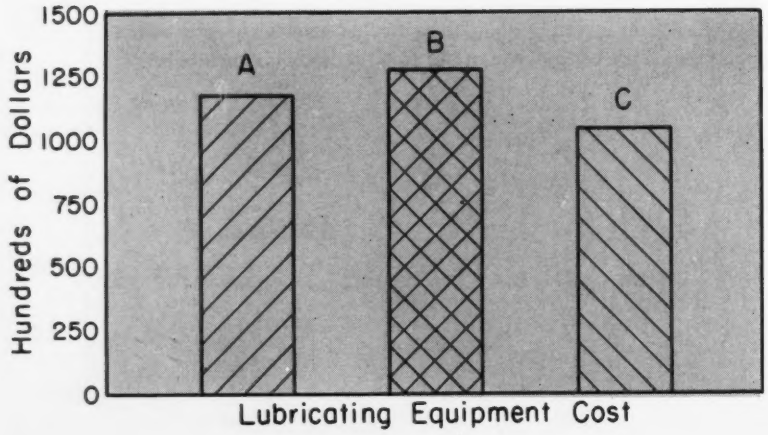


The rapid spread of modern lubrication practices has played and important role in the reduction of machine down time normally required for lubrication purposes. Extended machine life can be related directly to improved modern lubrication techniques and preventive maintenance programs. The basic idea of automatic lubrication is the application of small amounts of lubricant at definite time intervals in order to maintain better lubricant films on machine wear surfaces.

Industry Looks at Automation in Lubrication

by R. H. Cottrell
Lubrication Engineer
Sheffield Div.-Armco Steel Corp.
Kansas City Plant





The application of automatic lubrication systems not only maintains a better film, but, also releases maintenance personnel for necessary inspections required by preventive maintenance programs. The actual cost of equipment and installation can be paid for by the reduction of time normally required to lubricate the machine. The time required for installation and cost of the automatic equipment depends on the complexity of the machine; therefore, the more complex the operation the greater the labor saving and the shorter the time required to retire the cost of auxiliary equipment.

Lubrication in a modern steel mill is probably one of the most diversified programs found in any industry today. The methods of applying lubricants present many problems that must be faced immediately by those charged with the responsibility for operating and extending the life of equipment.

Methods of production in the steel industry have undergone many changes. For example, the mule-drawn ore cart with "hard-oil" lubricated, plain bearings is now replaced with the high-speed ore conveyor with rolling-contact bearings lubricated by an automatic lubrication system. These and many other modern developments owe their successful operation and longevity to a very important factor—proper lubrication.

Like many other manufacturers using heavy equipment, the steel industry finds that the normal life expectancy of basic capital equipment is 25 to 50 years and longer in some cases. The problem of modernization of this equipment may arise several times during its normal life. Progressive companies never lose sight of the fact that after modernization takes place, the original design and capacity of the equipment may have been exceeded many times. Often under these circumstances, bearings and gears are operating under marginal lubrication conditions. Therefore, a properly designed, modern lubrication system for the bearings and an improved gear lubricant will allow the equipment to operate with a minimum of delay until it has again reached another modernization period.

Machine down time on the above capital investments is often calculated in hundreds of dollars per minute. Here then is the opportunity for modern automatic central station lubricating equipment to prove its merit in preventing machine down time due to the lack of proper lubrication. The trend toward fewer down periods is very apparent as industry modernizes its equipment. The lack of these periods, often referred to as mill lubrication delays, has stressed the importance of better lubrication methods.

WHAT TO CONSIDER IN A LUBRICATION SYSTEM

One of the most outstanding advancements in lubricating equipment today is the development of the automatic central station lubricating device that provides metered lubricants under positive pressure to the bearings. The ability of equipment manufacturers to keep abreast of the time with their modern pump designs and development of a large selection of metering valve sizes has made it an easy task to select a system that is economical to install and can be justified.

It is difficult to sell management on auxiliary equipment unless adequate proof of the value of such expenditure can be clearly justified.

There are unlimited opportunities in an industrial plant to improve the lubrication of machinery by the the application of automatic, semi-automatic or manually operated central lubrication systems. An industrial lubrication engineer must use all the modern devices at hand to cope with each problem that arises. However, he must never lose sight of the fact that each problem is a practical one which must be heavily weighed against the economical aspect of the situation as well as the other advantages to be gained. It is, therefore, important to keep in mind the following factors when considering a system:

1. Capital equipment investment.
2. Machine production demands.
3. Complexity of lubrication requirements.
4. Lubricating equipment cost.
5. Lubricating equipment installation cost.
6. Routine lubrication cost and time requirements.

After giving full consideration to the above conditions, if it is found to be a sound investment to install a modern lubricating system on the existing equipment, the following requirements should then be considered before selecting an automatic central lubricating system:

1. Complexities of lubrication equipment operation.
2. Flexibility of equipment.
3. Equipment standardization.
4. Equipment service life.
5. Training necessary for personnel.
6. Ease of installation.
7. Salvage value.

In reviewing the above requirements for selecting a modern lubrication device, it is important to understand the operation of each system before making the choice.

Complexity of Lubrication Equipment Operations. The successful operation of any system depends on how complex the operational instructions are. If these instructions are complicated, the system will fail because of sheer neglect of attention. Simplicity of operation is paramount.

Flexibility of Equipment. There are several factors that may determine the flexibility of a system. For example; "Will the system handle fluid as well as nonfluid lubricants?" or, "Can the metering system be easily changed after installation?" "How flexible are the automatic control and alarm systems?"

Equipment Standardization. Equipment standardization, in the writer's opinion, is one of the most important considerations in the entire plant lubrication program. Standardization will reduce spare part inventories, limit the need for extensive training for personnel and speed repair work.

Equipment Service Life. Equipment service may or may not be a function of quality. The service life of equipment in the steel industry may be extremely short if the lubrication device is not built to withstand rough service. However, the same equipment applied to another phase of the manufacturing process may last indefinitely.

Training of Personnel. Every industrial plant should provide training on equipment in order to insure trouble-free operation. Many cases of failure can be traced to a misunderstanding of operational procedure.

Ease of Servicing. All systems when installed should be made with ease of servicing in mind and should present a neat appearance to the machine operator and maintenance group. If properly installed and if the appearance is good, service life should be satisfactory. The location of metering valves should be made so as to facilitate machine repair.

Salvage Value. The salvage value is not often given consideration when selecting modern lubrication equipment, but due to the extended life and service of this equipment, salvage should not be overlooked because of the flexibility of some equipment.

Economic Aspects. The old drip system that might be considered an inexpensive central lubricating device has often been proven to be the most expensive system that could be installed on a machine.

For example: The polished brass drip feed sight glass costs only about $3.15 and has a wide range of control from a drip to a steady stream. The system must contain a lubricant supply which is normally located about six to eight inches above the machine. This supply ranges from one quart to five gallons. Long delivery lines must lead from the drip oiler.

The above system has all the requirements necessary to provide a machine with general lubrication. Now consider the shortcomings of this equipment.

The range of control of a needle valve sight glass drip oiler will cover the entire range from a drip in the morning to a steady stream in the afternoon. The oil reservoir may contain the exact requirements for the machine operating under ideal conditions, but this is not often found to exist. In the event that ideal conditions are not attained, the machine either operates in feast or famine. Under either of these conditions, the term "Proper Lubrication" could not be applied and normally the machine has excessive maintenance cost.

A modern lubrication approach to the same problem would reveal that the cost of a single metering valve would range between $3.50 and $4.75 as compared to $3.15 for the sight drip oiler. The added expense for the pumping unit must be divided equally among the number of lubricant points, and it should not raise the cost more than $3.00 per bearing point.

The natural reaction to these figures would be that the cost per bearing point has been doubled. It must be remembered that the larger the automatic system, the lower the unit bearing cost.

After analyzing several jobs that required lubrication task, it was established that the average time required to lubricate a bearing point on a machine was 2.83 minutes per point.

Converting time into cost figures, based on an oiler's job classification under the present steel contract, this amounts to 10.13 cents per point. Neither the time nor the cost per point seems excessive on the face of the problem, but the overall picture is another story.

If an oiler spends only the average time established in the survey, the total number of bearings to be lubricated in an eight-hour day would be 169.6 bearings at a labor cost of $17.18. It is very doubtful that a man could perform this task on a 100 per cent efficiency basis for a full eight-hour day.

Based on a cost of $7.85 per bearing point, the labor cost alone would pay for 2.18 bearings to be covered by a modern lubricating device per day.

The advantages of an automatic lubrication system are many, but consider the one advantage that all automatic systems have in common, the replenishment of the lubricant film to the bearing at short intervals of time. This one advantage alone cuts bearing wear, reduces lubricant consumption, improves machine cleanliness, general housekeeping and plant safety.

The graph on the first page of this article indicates the capital equipment investments, lubricating equipment investments, and labor costs on three recent installations at a Kansas City plant. (Original equipment manufacturer's installations were not reviewed because it was difficult to extract the exact cost of equipment and labor cost from the original price of the capital equipment.)

The graph shows a capital equipment cost of machine A as $250,000. The automatic lubricating equipment on this machine increased the initial investment .47 per cent, while the labor cost of installing the lubricating equipment raised the initial cost an additional .28 per cent. The total cost of an automatic lubrication system installed on machine A was only .75 per cent of the capital investment.

(*Cont. on page 492*)

Lubricating Oil Filtration—

Clean lubricants in engines and other lubricated systems are a necessity. An analysis has been made of the characteristics and functions of various methods of accomplishing the optimum results—emphasis is on permanent filtration and the best filter media available today.

Aspects Related to the Economics of Engine and Machine Operation

*by R. A. Howland**

Filtration and its value in the operation of lubricated machinery is intimately associated with the theory that wear on moving surfaces could not occur if those surfaces were totally separated by a film of clean lubricant. Therefore, if an engine or other lubricated system were permanently and continuously supplied with an oil of correct characteristics for the machine and the specific operating conditions and maintained at all times completely free of all contaminants, both soluble and insoluble, it could be expected that trouble-free operation for an indefinite period of time with high mechanical efficiency could be achieved.

Effects of Contaminated Oil

It has long been recognized that mineral oil does not wear out as a result of service, but if preventive maintenance measures are not employed, it is possible for contaminants of various types to accumulate in the lubricant, which in time can ruin any mechanical system in which it circulates. These harmful contaminants carried and deposited by a flowing lubricant throughout a mechanical system exist in several forms, soluble and insoluble. Some of the soluble contaminants are highly corrosive acids which are strong enough to cause etching and pitting of metal surfaces, while others reveal themselves as deposits of varnish, gums, and sludges which restrict oil channel openings, clog strainers, foul heat exchangers and oil coolers, stick rings. They increase friction, causing power loss, inefficient cooling, and general reduction of operating efficiency. The insoluble and abrasive contaminants make their presence known by grinding and abrading away surface metal from parts such as bearings, cylinder walls, crank shafts, timing gears, oil pump gears, et cetera. The effects of the action of these harmful materials, which in some way attack every part of a lubricated system, are known to contribute more to the necessity for the replacement and repair of parts, to the loss of operation and production time, and to other items of maintenance and expense than any other single factor involved in the operation of internal combustion engines and other types of machines.

There are three methods in general use in the approach toward the maintenance of lubricating oil quality. They are (1) draining the dirty lubricant from the machine and refilling with clean lubricant, either new or reconditioned; (2) periodically attaching a portable filter to the machine and circulating the lubricant through the filter and machine until the lubricant is restored to satisfactory condition for further use, (3) or using permanently installed filters.

Draining and Refilling

In the draining and refilling method, it is physically impossible to drain all of the dirty oil from the system even though the draining operation is carefully performed. An indefinite quantity of contaminated oil is invariably left in the system, caught in pockets in inaccessible areas. Although the dregs of contaminated oil are in small quantities, they, immediately upon mixing with the new oil, become a very active accelerator in the rapid promotion of deterioration in the new oil.

Periodic Filtration

The periodic use of a filter is more effective than the draining and refilling method as inaccessible pockets or areas which cannot be completely drained will be reached and cleaned by the circulating and flushing

* The Briggs Filtration Co. (subsidiary of Bowser, Inc.), Washington, D. C.

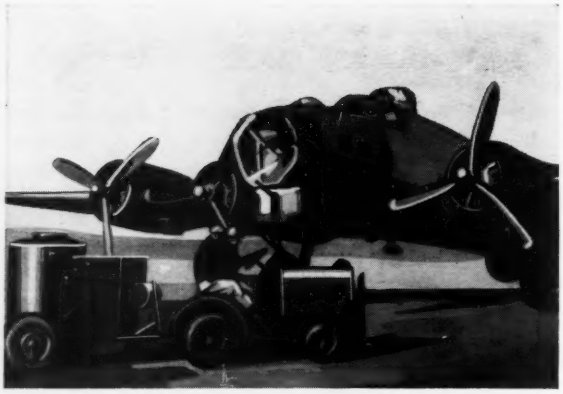


Figure 1. Portable filtration system for aircraft engines

action of the clean oil. The superiority of the periodic filtration of lubricating oil was demonstrated emphatically during World War II when it was found that only approximately 60 per cent of the oil could be removed from the average aircraft piston engine by normal draining methods. Early in the war, the *Air Force Technical Operating Instructions for Engine Maintenance* called for red-lining or changing out aircraft engines at the end of approximately 350 to 400 hours of operation. This requirement for frequent engine changeout was 75 to 80 per cent a direct result of accumulation of contaminants in the lubricating oil.

To secure more service from the aircraft, the portable self-contained filtration system shown in the illustration was developed which consisted of a filter equipped with a gasoline-fired steam boiler capable of heating and maintaining the oil at 190F. while circulating it through the engines at a flow of 50 gpm. The high pump and filter capacity was provided to effect high velocities and consequent flushing and scrubbing action within the aircraft engines. The hot clean oil was circulated through the engines and filters while the engines were idling for approximately 15 to 20 minutes each time the aircraft returned from a mission, when possible. Even though these filters were used only intermittently, their use made it possible to increase to 1,200 hours' operation the red-lining of the engines which were receiving the service of the portable filters. The secret to the improvement in engine availability was to a great extent due to the ability of the high velocity and turbulence of the hot clean oil to reach into pockets and flush out dirt and dissolve deposits that could never have been disturbed by normal draining and refilling methods. However, with both the draining and refilling and the most effective periodic filtration methods, an engine or a machine will not receive the protection of good lubrication at all times. Instead, a condition of maximums and minimums will be effected in the quality of the lubricant. The cleanliness of the lubricant after draining and refilling or periodic filtering cannot restore parts of the machine that may have been damaged while the lubricant was in a dirty or minimum quality condition prior to the application of the filter or before draining and refilling with clean oil.

Permanent Filtration

With properly selected, permanently applied filters of adequate capacity, it is theoretically possible to maintain oil at close to new oil standards almost indefinitely, provided the additive content of fortified oils is not allowed to deplete beyond levels considered adequate by the oil supplier.

By-pass Filtration

The first advance from the metal strainer to the true filter was the introduction of the by-pass filter system, in which the filter continuously cleans or rectifies a small portion of the oil flowing in the lubricating system. In this method a predetermined quantity

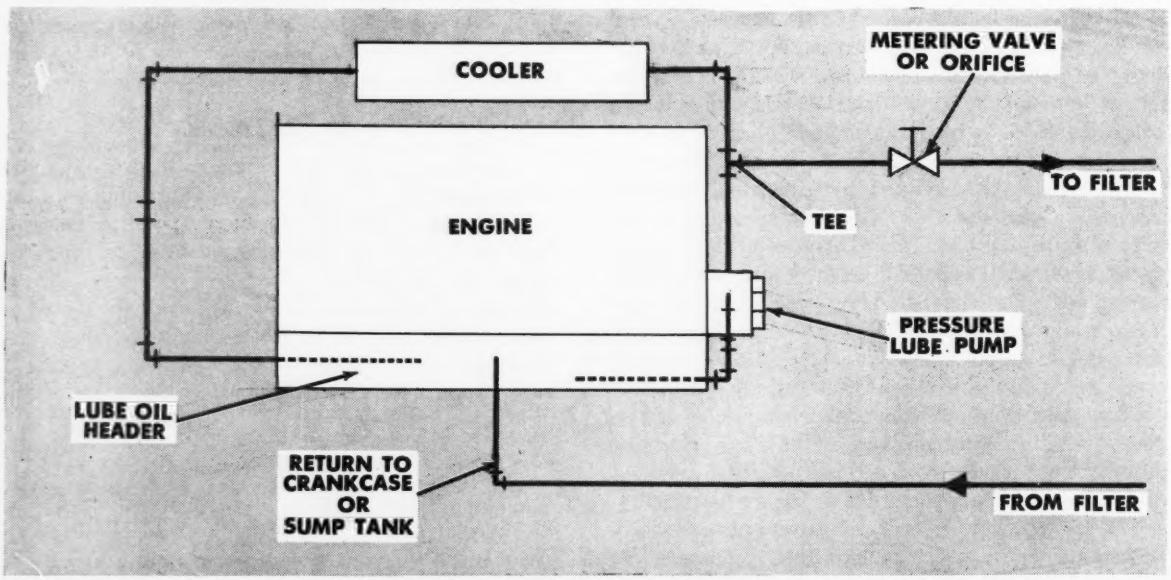


Figure 2. Typical by-pass filter system

of oil is taken from the system at a point preferably between the lube oil pump and the oil cooler, where the highest oil temperature is available, and diverted through the filter and directly back into the system's oil sump at a rate usually fixed by a set valve or other flow control device. The filtered oil generally consists of approximately 10 per cent of the system's pump capacity, leaving the remaining 90 per cent of the oil circulating in the machine without filtration, until such time as it eventually reaches the filter. Satisfactory performance of the by-pass system is predicated on the ability of the filter cartridge to remove dirt on each pass faster than the rate at which the dirt is being introduced into and produced in the oil. The weakness of the by-pass system is that the dirt-making rate of engines of equal horsepower ratings will differ greatly with different types and designs of engines. Also, engines of given horsepower will be equipped with lubricating oil pumps of different flow capacities. On the average two-cycle gas engine, a by-pass filter handling approximately 10 per cent of the flow rate of the lubricating oil pump generally maintains nonadditive oil satisfactorily in a condition of visual cleanliness. Cleanliness of the total quantity of oil in the system using a by-pass filter is actually accomplished through dilution of the main body of oil with clean, filtered oil.

Shunt Filtration

Another popular method is the shunt filter system in which all the oil flowing from the lubricating pump passes through the filter case, wherein it is divided, part of the oil passing through the filter cartridges and part passing through the internal relief valves. Beyond this, the two streams of oil mingle to become a blend of filtered and unfiltered oil which is returned to the lubricating system. The condition of the oil in the sump of a lubricating system using the shunt type filter is identical to the condition of the oil in a lubricating system on which the by-pass filter system is in use. In the shunt type filter system, the quantity of oil filtered is only that portion which the

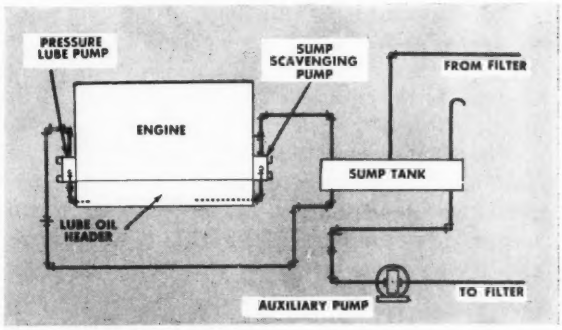


Figure. 4. Typical independent filter on marine engine sump tank

pressure drop or differential through the relief valves can force through the filter cartridges. The quantity of oil passing through the cartridges will vary with the density of the filter media and with the increasing restrictions of flow as the dirt load builds up thicker and thicker on the cartridges.

Independent Filtration

The independent filter method is employed frequently and consists of a filter equipped with its own pump which is usually electrically driven and operates independently of the machine's lubricating oil system. The independent filter takes a suction and returns the oil to any convenient place in the engine or machine sump which will not permit the establishment of a short circuit. With this independent filter system, oil can be maintained in very good condition, provided the filter and its attached pump are large enough to filter the oil at a flow rate which will permit the removal of contaminants as fast as or faster than they enter the oil. The independent filter is generally specified for the older type engines having lubricating oil pumps of low capacities and for engines that are subject to frequent shut-down when no pressure would be available to operate an engine-attached filter.

Full-flow Filtration

In the true full-flow system, all the oil circulated by the lubricating oil pump continuously passes

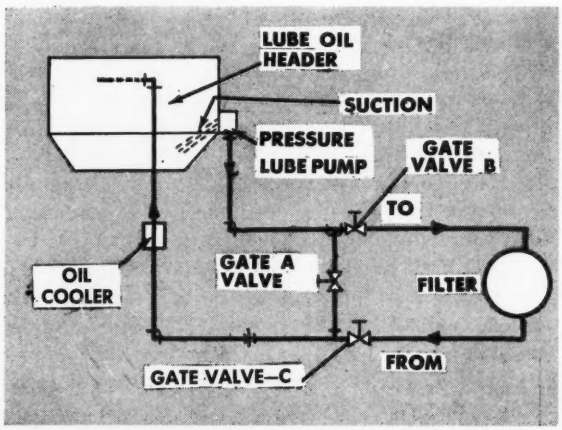


Figure 3. Typical shunt filter system

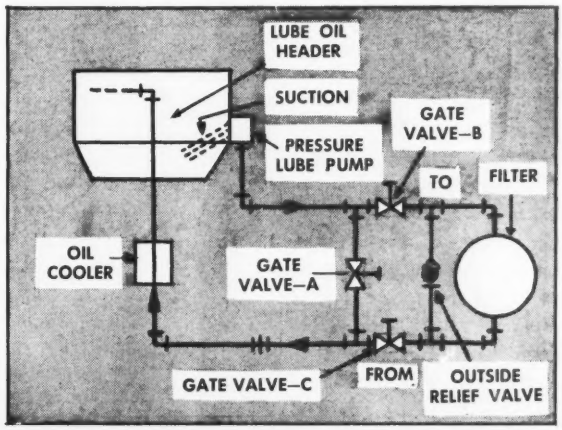


Figure 5. Typical full-flow filter system with outside relief valve

through the cartridges in the filter. Both shunt filters and true full-flow filters are equipped with relief valves. However, in operation, there is an important difference in the functions of the relief valves in the true full-flow filter and the shunt filter. The shunt filter is designed to operate normally with the relief valves open, whereas the full-flow filter is designed to operate with the relief valves closed in order to provide 100 per cent filtration on all oil on each pass through the system.

The true full-flow filter operates on very low pressure drops with the relief valves set to open at some preselected pressure, depending on the requirements of the system. The relief valve settings can be anywhere from 10 to 20 psi and may be set as low as 5 psi, depending on conditions that exist within the particular lubricating oil system. In the operation of a true full-flow filter system, optimum results are secured when the cartridges in the filter are changed before the pressure drop reaches the pressure at which the relief valves are set to open. Internal relief valves within the full-flow filter are not recommended. When an internal relief valve opens because of deposits of dirt and increased pressure drop through the filter cartridges, the resulting high velocities and violent turbulence generated within the filter can dislodge dirt that has been caught on the filter refills and wash it back through the open relief valve into the engine.

Combination Filtration

The nearest approach to perfect oil maintenance and engine protection appears to be through a combination filter system in which both full-flow and by-pass filters operate simultaneously. It is possible to secure the full advantages of both types of filter performance only with this system. The by-pass filter cannot handle the heavy dirt load and high flow required of the full-flow filter, nor can the full-flow filter stop the extremely fine particles of dirt the by-pass filter does. However when the two types of filters are operated simultaneously, one becomes a valuable adjunct to the other, offering the most nearly perfect continuous oil-rectification system that it has been possible to devise with the equipment available today. The combination system is recommended for both straight mineral oil and additive oil maintenance.

On straight mineral oil, the use of fuller's earth or other types of adsorbent cartridges is recommended in the by-pass filter for correcting of acidity and removing other soluble contaminants. For the maintenance of additive oils, it is necessary to use inert type cartridges in the by-pass filters to prevent the removal of additives from the oil.

The initial cost of the combination filter system may be twice the cost of the individual filter; however, the improvement in engine operation and the reduction in maintenance expense made possible by the combination system will more than justify the greater first cost.

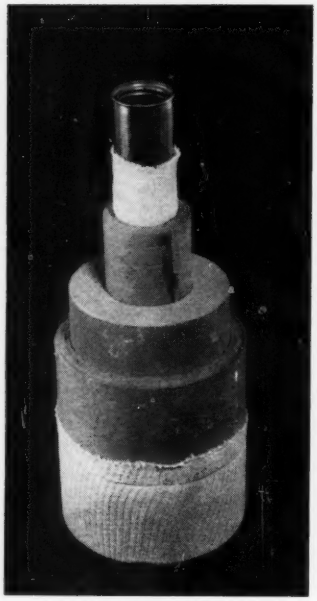


Figure 6. By-pass fuller's earth type filter cartridge

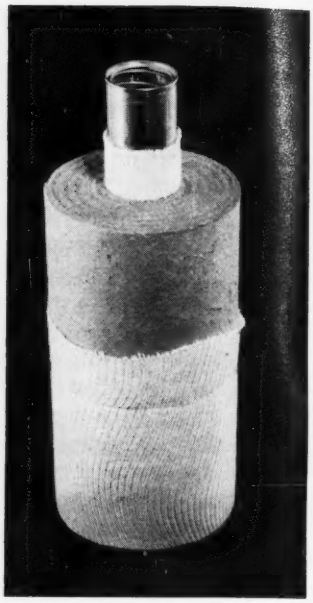


Figure 7. By-pass depth type cellulose filter cartridge

Modern Filter Cartridges

The development and availability of effective flull-flow filters beyond screen and metal-edge strainer types was not possible until media were available that could provide the flow rates necessary and at the same time stop dirt particles in sizes down to the range that could prevent or mitigate excessive engine wear. Filter media with these characteristics are now available and are continually being improved to provide lower pressure drop, higher flow rates, and finer particle selection. Much of the recent wider acceptance of and need for 100 per cent full-flow filtration systems can be attributed to the development of the modern higher-output, higher-speed engines with closer tolerances. The introduction and increasing use of the aluminum bearing and other special purpose materials, which cannot tolerate the dirt and contaminants the old slow-speed engines with Babbitt bearings having clearances of .005 and more could tolerate, have also accelerated this need.

There are several materials available from which satisfactory, single-purpose by-pass and full-flow lubricating oil filter cartridges can be made. However, the universal filter medium that can provide particle selections equal to the selectivity of the cellulosic, depth-type, by-pass filter cartridge, while simultaneously providing the high flow at low pressure drop required in the full-flow filter, has not been discovered. The selection of filter media most satisfactory for various types of filter applications is, therefore, one of compromise.

On the basis of approximately ten years of development through laboratory and field experience, the media so far found best suited for full-flow filtration

appear to be paper discs super-imposed and stacked to desired heights, controlled-density paper fluted or Z-folded to selected sizes and shapes, and yarn-like materials wound into cylindrical shapes. With cartridges of these types, it is possible to provide filtration whereby up to 98 per cent of all solid particles over 15 microns in size can be removed from the oil on each pass through the cartridge while maintaining maximum flow rates with minimum pressure drops. Full-flow cartridges of particle selection down into the five-micron range are also available for applications with special requirements, such as protection of surfaces operating with highly critical clearances in extreme pressure hydraulic mechanisms and for aluminum bearings in internal combustion engines. In a super-imposed disc-type cartridge, 18 inches long by approximately 7 inches in diameter, 2,000 square inches of filter surface are available, whereas in the fluted or Z-folded paper cartridge of the same size, an area of 6,300 square inches or 44 square feet is available. The tremendous areas in these cartridges are the secret to low pressure drop, high flow characteristics. The contribution of area to the success of a full-flow filter cartridge is recognized when it is considered that in a depth-type cartridge, 18 inches long by seven inches in diameter, approximately only 395 square inches of filter area will be available.

Flow Characteristics of Filter Cartridges

A comparison of flow rates available in the various types of filter cartridges of equal dimensions shows that on oil having a viscosity of approximately 150 SUS, the average viscosity of engine lubricating oil at normal operating temperatures, the average depth-type cartridge will have on a 10 lb pressure differential flow rates of from ½ gpm to approximately 10 gpm, depending on media and type of construction. On the same viscosity and pressure drop, the superimposed disc-type cartridge will have a flow rate of approximately 24 gpm, whereas with the same size cartridge under the same conditions in the Z-folded or fluted

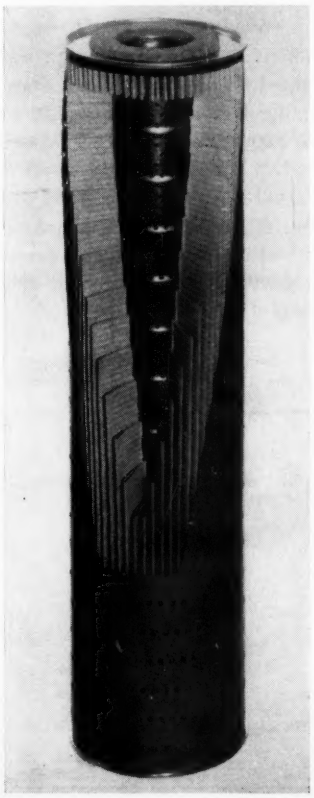


Figure. 8. Full-flow Z-folded paper filter cartridge

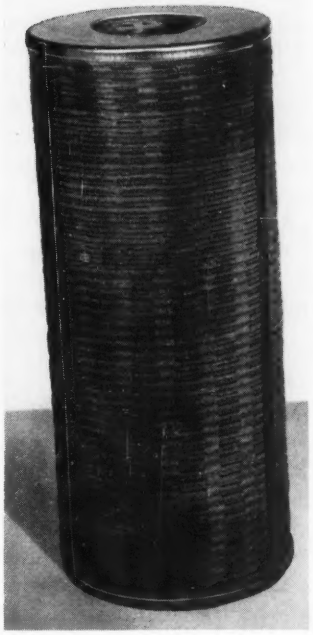


Figure 9. Full-flow or by-pass superimposed paper disc filter cartridge

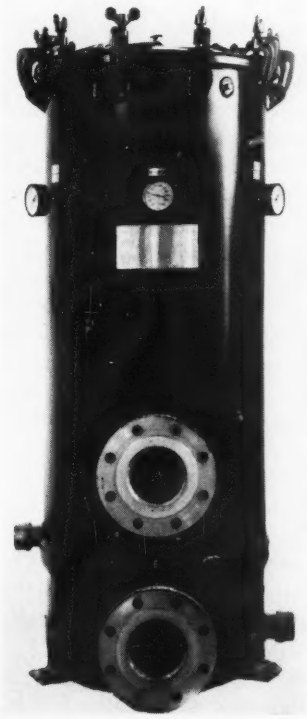


Figure 10. Popular type modern filter case for by-pass or full-flow application

type construction, flow rates of over 35 gpm are available at a pressure drop of 1 pound. The super-imposed disc-type cartridge and the Z-folded or fluted-type construction are strictly surface-type cartridges and cannot be compared to the depth or by-pass types in ability to stop some of the finer particles in the range of ¼ to 1½ microns. The paper-type cartridge, the fluted Z-fold type, and the wound-yarn type, while unable to stop as many of the particles of extremely small range that will be stopped by the by-pass or depth-type cartridge, will stop and retain the larger particles much more effectively than the so-called depth-type cartridge.

Filter Case Design

To secure the maximum benefits the modern filter cartridge offers, it is necessary to contain it in a case or vessel so designed that any fluid entering the filter case must pass through the cartridges in order to leave the filter case and return to the lubricating system.

To insure the best possible maintenance, the filter should be as attractive as possible to maintenance people. The parts which must be handled physically should be as light as possible with a minimum of studs and bolts, a minimum requirement for the use of tools, a minimum of gasket replacements, fool-proof installation of refill cartridges, a minimum of oil drain-down, and provision for the least possible mess and oil slop-over when changing cartridges. The filter case should be designed to reduce parasitic oil to a minimum; i.e., oil that is not working or being filtered. It should also be designed to eliminate the possibility of stratification of heat, to afford equal distribution of fluid to all cartridge surfaces within the case, and to provide suitable baffling of incoming fluid to prevent jet action or spot pressures against cartridges.

Adequate Filtration Pays Off

Because of space limitations, the railroad diesel locomotive engine is equipped with filters less than one half as large as they should be. The United States Navy specifies for its diesel engines filters double the size for the same horsepower ratings as those found in locomotives, and even those filters are too small. The diesel tow-boat operators have proved to themselves by the reduction of maintenance costs that clean lubricating oil more than justifies the cost of their filters, which are generally twice the size the Navy specifies.

As an illustration of what the size and capacity of the filter can mean in improving the operation of an engine, a tow-boat operator on the Mississippi River has two boats which are identical in every respect except for filters. The filter on one boat is twice the size of the filter on the other boat.

After one year of operation from the time the boats were put into service, the owner replaced the small filter with one equal to the size of the large filter. He reported:

"On the engine with the eight-element filter, it took 60 to 70 hours of operation to clean up the oil after the elements were changed. Only reasonably clean oil could then be maintained for the next 200 to 225 hours. The oil was sufficiently contaminated at the end of 450 to 500 hours of operation to require the changing of the filter elements. On the engine with the 16-element filter, full clean-up of the oil took place within 24 hours after elements were changed. Bottle-clean oil was then maintained for the next 750 to 800 hours, and refill change was not necessary until after 1100 to 1200 hours of operation. Four times during the year, it was found necessary to remove pistons from the first engine to free rings; the second engine ran all year without any trouble."

Actually, the first engine with the small filter ran only 40 per cent of the time with clean oil; yet the cost for filter operation was less on the second engine with the 16-element filter, which ran 70 per cent of the time on really clean oil.

Another demonstration of the mechanical and economic benefits available through the use of adequate filtration is the experience of an operator of a tow boat out of New Orleans whose vessel is powered with a 900 horsepower diesel engine. The engine was originally equipped with a 10-element filter to which another 10-element filter later was connected for parallel operation. The first effect attributable to the increased filter capacity was a reduction in expense of from an average of $2,600 to an average of $1,250 for routine 5,000-hour engine overhaul operations. Overhaul periods have since been increased to 10,000 hours, and the operator reports no increased requirement for the replacement of rings or bearings.

These instances of improved operation and reduction in maintenance costs made possible through the use of adequate filter protection are not isolated ones. Similar results are becoming increasingly common as knowledge grows through experience and observation.

High-quality, adequately sized, properly applied filters do not constitute a cure-all. However, field experience is demonstrating in all industrial machine operations that clean lubrication is one of the most important maintenance tools available for over-all efficient engine and machine performance.

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Chemical Conversion Coatings for the Lubrication of Titanium

*by E. L. White and P. D. Miller**

ABSTRACT

Titanium and its alloys have a severe tendency to seize and gall when in moving contact with themselves or other metals. Lubrication of the bare metal has been successful only to a limited extent. Galling can be greatly reduced by using chemical conversion coatings with lubricants. Both anodic coatings and simple dip coatings hold lubricants effectively and eliminate or reduce galling in wear applications. The results of wear testing, wire drawing, and cold forming of sheet using conversion coatings are discussed. A satisfactory coating can be formed on titanium by anodizing in a 5 per cent solution of NaOH. A fluoride-phosphate conversion coating can be formed by simple immersions in a solution containing HF, KF, and Na_3PO_4.

INTRODUCTION

Titanium was announced a few years ago as the wonder metal of the age. Its useful properties include its light weight, high strength, and excellent corrosion resistance. However, the wear resistance of titanium and its alloys has proved to be very poor. This behavior limits applications and contributes to the high cost of some finished titanium forms. For example, drawn tubing or wire presents problems to the titanium fabricators because of seizure in the dies.

Titanium is particularly susceptible to galling, in which there is a transfer of metal from one surface to another. Though all metals tend to gall to some extent, usually some type of lubrication or a lubricant plus a suitable mating surface can be found to overcome this tendency.

There has been little success in lubricating titanium with the many lubricants originally developed for use on other metals. Galling persists in spite of good lubrication techniques, even under light loads and at slow contact speeds.

COATINGS

The most improvement in the wear resistance of titanium and its alloys has been attained by modifying the surface by means of coatings. Depending on the service application, the choice is between chemical conversion coatings and metallic coatings. Metallic coatings furnish the best results for severe wear applications, while the conversion types are satisfactory for mild wear conditions. The present discussion is confined largely to the conversion coating group.

A chemical conversion coating may be defined as a coating which is formed on the surface of a metal by chemical or electrochemical reactions with some medium. The medium may be a solid, a liquid or a gas. Usually it is a liquid which can be applied by spraying, brushing, or total immersion. This distinguishes a conversion coating from other coatings which are first prepared and then applied to the surface of a metal or from coatings which are formed by hardening treatments which may change the surface properties of the metal itself.

In forming a conversion coating, one or more of the elements in the alloy combine chemically with one or more of the elements from the active medium to form a tightly adhering layer. This surface layer will have many chemical and physical properties which are very different from the properties of the base metal. In this sense, all corrosion products which adhere well could be considered conversion coatings. However, for practical purposes, there must be a fairly rapid reaction rate between the metal and the medium to produce the required coating in a reasonable length of time. Titanium's good corrosion resistance presents problems in finding a medium which will react rapidly with its surface. If a conversion coating is to be used in forming operations, another factor to be considered is that it must be easily removed after the forming operation is finished and a reasonably smooth surface must be retained.

For many years, conversion coatings have been used primarily to protect against corrosion, to improve paint bonding and adhesive bonding, and to decorate. On other metals, zinc and manganese phosphate treatments produce coatings which find application in both increasing the wear resistance of machine parts and in extending die life in forming operations. Some of the coatings produced on aluminum and magnesium by anodizing are examples of coatings used in wear applications.

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COATING TREATMENTS

In order to determine the most suitable conversion coatings for titanium, a large number of materials was studied in a fairly extensive laboratory research program. Several hundred solutions compositions were examined for effectiveness in producing useful coatings.

A selection of some of the compounds used to make up solutions for this study is given in Table 1. The solutions were tried as simple immersion baths and as anodizing baths. Many of the solutions produced very thin colored coatings or coatings which were not adherent.

TABLE 1. TYPES OF COMPOUNDS INVESTIGATED FOR PRODUCING CONVERSION COATINGS ON TITANIUM AND ITS ALLOYS

Hydroxides	Cyanides	Oxalates
Aluminates	Carbonates	Acetates
Phosphates	Fluorides	Tartrates
Sulfates		
Sulfides	Peroxides	Benzoates
Chlorides	Fluoborates	Permanganates
Chlorates	Fluosilicates	Chromates
Nitrates	Borates	Formates
Nitrites		

Table 2 shows some of the solutions which produced good coatings through the use of an impressed current. The wear performance of the anodic coating formed in a sodium hydroxide bath (No. 1) is very good. The coating is relatively thick and holds the lubricant well. Fairly good coatings were obtained by the rest of the anodic treatments shown. In addition, anodic coatings can be produced in a great many other baths; however, many of these adhere poorly or are very thin. The color of some of these thin coatings vary with treatment time, which indicates that the color results from an interference phenomenon. Though these coatings are too thin for wear application, they are quite decorative and have other uses.

The compositions of the five most promising simple immersion baths are shown in Table 3, the two most effective being Nos. 1 and 2. Both of these baths contain 50 g/1 of trisodium phosphate and 20 g/1 potassium fluoride. They differ, in that Bath No. 2 is higher in hydrofluoric acid than Bath No. 1. These two baths produce very similar coatings, but the solution with the higher proportion of hydrofluoric acid has the advantage of operating at room temperature and producing a coating in 1 to 2 minutes. This is in contrast to operation at 85 C and coating time of 10 minutes. Usable coatings are produced in the other three baths, but the quality is somewhat inferior to that of the fluoride-phosphate-type coatings.

A chemical analysis of the coating produced in Bath No. 1 shows approximately 39 per cent fluoride, indicating that a potassium-titanium-fluoride complex is formed.However, the exact chemical compound has not been determined. The coating produced in Solution No. 2 has a somewhat similar composition. In these baths, immersion time has an important effect on the quality of the coating. A maximum thickness of coating is produced in 10 minutes in one case and in two minutes in the other, after which the thickness remains essentially the same. However, overexposure to the bath somewhat lessens the adherence of the coatings. Commercially pure titanium and a number of alloys can be coated by either of the fluoride-phosphate baths. Some alloys require a modification of the hydrofluoric acid content of the bath to produce satisfactory coatings. With some alloys, the amount of hydrofluoric acid must be raised to as high as 160 ml/1 of 50 per cent hydrogen fluoride solution. This introduces the question of possible hydrogen pickup during coating. But hydrogen contamination of sheet stock, even in the high-acid baths, has been found to be within acceptable limits, probably

TABLE 2. ANODIC COATING BATHS

BATH NO.	BATH COMPOSITION	TEMP, F	TIME, MIN	CURRENT DENSITY, AMP/FT^2	DESCRIPTION OF COATING
1	100 g NaOH 1900 g H_2O	203	20	50	Sparkling gray, durable coat
2	25 g $NaAlO_2$ 5 g NaH_2PO_4 475 g H_2O	194	20	25–50	Gray-green, fairly hard coat
3	25 g Na_2O_2 5 g $NaH_2PO_4 \cdot H_2O$ 500 g H_2O	113	25	50	White, fairly hard coat
4	375 g $NaClO_3$ 375 g H_2O	77	30	7–12	Salty-white coat
5	800 g $Na_2CO_3 \cdot 10\ H_2O$ 800 g H_2O	203	10	25	Thin gray, fairly adherent coat
6	100 g $NaClO_3$ 900 g H_2O	77	20	3	Thin, very hard green coat
7	10 g NH_4HF_2 25 g NH_4OH 450 g H_2O 10 g $NH_4H_2PO_4$	176	10	35	Blue-white coat

TABLE 3. CHEMICAL-IMMERSION COATING BATHS

BATH NO.	BATH COMPOSITION	COATING TEMP, C	COATING TIME, MIN	PH	DESCRIPTION OF COATINGS
1	50 g/1 $Na_3PO_4 \cdot 12\ H_2O$ 20 g/1 $KF \cdot 2\ H_2O$ 11.5 ml/1 HF sol.†	85	10	5.1–5.2	Light silver gray, durable coating
2	50 g/1 Na_2HPO_4 20 g/1 $KF \cdot 2\ H_2O$ 26 ml/1 HF sol.†	25	1–2	1.0	Dark metallic gray, adherent coating
3	40 g/1 $Na_2B_4O_7 \cdot 10\ H_2O$ 18 g/1 $KF \cdot 2\ H_2O$ 16 ml/1 HF sol.†	85	20	6.3–6.6	Metallic gray, adherent coat
4	30 g/1 $Na_2C_2O_4$ 20 g/1 $KF \cdot 2\ H_2O$ 1 ml/1 HF sol.†	60	30	4.1	Dark gray coating (not reproducible)
5	75 g/1 $K_2C_2O_4 \cdot H_2O$ 25 g/1 $KF \cdot 2\ H_2O$ 3 ml/1 HF sol.†	65	30	4.6	Light gray, coating (not reproducible)

† 50.3 per cent HF by weight.

due to the presence of the other salts and short exposure times.

The use of conversion coatings in forming operations may necessitate subsequent removal of the coating. The fluoride-phosphate coatings are removed quite easily in the regular nitric hydrofluoric pickle bath by a 30-second to 1-minute dip which restores a smooth bright finish to the metal.

These coatings may also be modified by heat treatment for even greater wear resistance. A more resistant coating is produced by heating the coated metal at 800 F for two to five hours in the presence of air. The fluoride-phosphate coating markedly increases the oxidation rate of the base metal. A substantial layer of titanium dioxide is formed between the coating and the base metal, which significantly increases wear resistance in some applications. This heat-treated coating has the disadvantage of being much more difficult to remove and it also leaves a rougher surface.

WEAR STUDIES

The wear resistance of the coatings has been estimated by two general types of evaluations, namely forming and wear.

Table 4 shows the result of some wire-drawing experiments using conversion coatings. These experiments were made using a 22-foot laboratory drawbench and drawing the Titanium 75A alloy. No drawing was possible when bare metal was used with various lubricants. However, a combination of the fluoride coatings with ordinary drawing lubricants furnished smooth wire and tube reductions, with no evidence of galling. The coatings have also reduced the galling and pickup of titanium on dies in sheet-forming and cold-extrusion operations and have decreased the force required to make the operation.

Some indication of the wear properties of the coatings was obtained using three laboratory wear machines. Two of these were reciprocating types and the third was a rotary-type machine.

Figure 1 shows a shaper which has been adapted for measuring wear. A steel ball held in the moveable head of the shaper was moved back and forth across

TABLE 4. WIRE DRAWING OF TITANIUM USING IMMERSION COATING

COATING	DRAWING LUBRICANT	TOTAL REDUCTION %	NO. OF PASSES	NO. OF COATS	FINAL CONDITION
Bare	MoS_2-grease	——	0	—	Galled
Bare	Wax	——	0	—	Galled
Bath No. 1	MoS_2-grease	85.0	8	2	Smooth
Bath No. 2	MoS_2-grease	94.0	17	7	Smooth
Bath No. 2	Wax	68.3	7	3	Galled
Bath No. 2†	MoS_2-grease	70.0	7	1	Smooth
Bath No. 3	Lacquer-MoS_2	63.0	8	2	Smooth
Bath No. 3	MoS_2-grease	63.0	8	3	Smooth

†Heat treated 1 hour at 800 F.

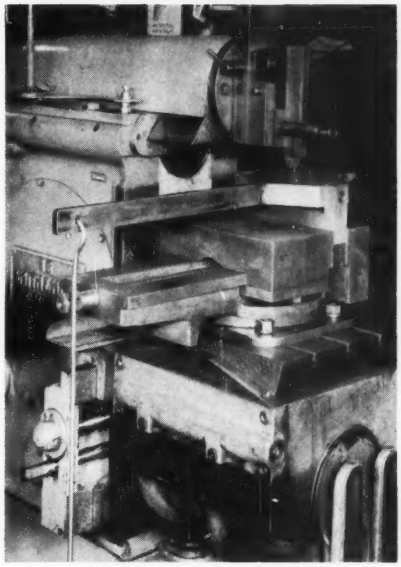

Figure 1. Sharper adapted for measuring galling

the surface. The two surfaces could be loaded to a pressure of 70 tons psi by means of the lever and weight arrangement shown in the photograph. Table 5 shows the results for pieces with and without the coating. Bare metal alone or bare metal with lubrication by a molybdenum disulfide grease galled badly on the first stroke. However, coated specimens run with machine oil ran up to 500 strokes without galling.

Other evaluations were run on the machine shown in Figure 2. This machine, which operated at much lower pressures, gave similar results. This machine consisted of a device for rubbing a quarter-inch lapped button back and forth on a wear plate which was immersed in SAE 30 machine oil. Table 6 shows some of the results of experiments run on this low-pressure reciprocating machine. A bare titanium button against a steel plate showed galling on the first stroke and bare titanium against bare titanium was no better. The fluoride- phosphate coating, without heat treatment, improved the wear a little but would be considered unsatisfactory for long-term wear application. However, the heat-treated coating lasted over one million cycles with no failures. This is the type of

TABLE 5. HIGH-PRESSURE† WEAR STUDIES ON COATED RC-55 ALLOY

FINISH	LUBRICANT	NO. OF STROKES	FINAL CONDITION
Bare	None	1	Galled
Bare	MoS_2-grease	1	Galled
Bath No. 1	None	1	Galled
Bath No. 1	Machine-oil	250	Smooth wear track
Bath No. 1	Machine-oil	357	Wore thin
Bath No. 1	Machine-oil	500	Smooth wear track
Bath No. 1	MoS_2-grease	500	Smooth wear track

†70 tons per square inch.

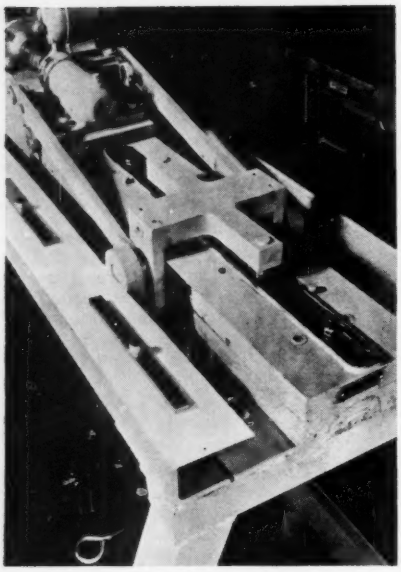

Figure 2. Apparatus used for studying reciprocating wear

TABLE 6. RECIPROCATING WEAR STUDIES

TYPE OF COATING ON WEAR SURFACE†		800 F OXIDATION,	LOAD,	NO. OF STROKES TO
TITANIUM BUTTON	WEAR PLATE	HR	PSI	GALLING
Bare	Steel	0	400	1
Oxidized	Steel	2	2500	4500
Bath No. 1	Steel	0	400	15
Bath No. 1	Steel	3	2500	1,018,298††
Bath No. 1	Steel	5	2500	1,136,898††
Bath No. 1	Steel	3	1250	90,000††
Bath No. 1	Steel	1	2500	79,000
Bath No. 3	Steel	1	2500	79,581
Bare	Bare titanium	0	600	4
Bath No. 1	Bare titanium	0	600	8
Bath No. 1	Bath No. 1 on Ti	0	550	17

†All work was done under SAE No. 30 oil.
††Machine was stopped before galling occurred.

TABLE 7. HIGH-SPEED ROTARY-WEAR STUDY ON TITANIUM

FINISH	OXIDATION AT 800 F, HR	RESIN†	LOAD, PSI	TIME, HR	RUNNING COEFFICIENT OF FRICTION††	FINAL CONDITION
Bare	0	No	200	0	—	Galled instantly
Bath 1	0	No	400	0.01	—	Galled instantly
Bath 1	5	No	400	3.6	0.047	Galled
Bath 1	19.5	No	600	6.7	0.014	Galled
Bare	0	Yes	600	0.67	———	Galled
Bare	2	Yes	600	0.73	———	Galled
Bath 1	2	Yes	600–800	199.0	0.017	Undamaged
Bath 1	2	Yes	600	161.5	0.062	Undamaged
Bath 1	2	Yes	600–800	225.0	0.072	Undamaged
Bath 2	0	Yes	800	273.0	0.069	Undamaged

† One part molybdenum sulphide in two parts epon-phenolic resin.
†† Average. All tests were run under SAE No. 30 oil.

an application in which heat treating the coating would be most advantageous. Figure 3 illustrates the appearance of wear specimens.

Results of rotary-type wear tests are shown in Table 7. The conditions on this machine are much more severe than those of either of the reciprocating assemblies. The coated specimens were counter rotated against a rotating steel plate. Again, it can be seen that the bare metal galled instantly.

In these studies, a solid lubricant bonded in a resin was applied to the specimens and the whole assembly was run under No. 30 machine oil. The coating without the solid lubricant galled within a relatively short time. The heat-treated coating ran somewhat longer, and uncoated specimen with the solid lubricant or uncoated oxidized specimens with the solid lubricant also galled after a short period of time, whereas the measurements involving coating plus solid lubricant or oxidized coating plus solid lubricant lasted 200 times as long. This indicates that the coating not only improves lubrication by liquid, but also promotes better bonding of a resin-bonded solid lubricant.

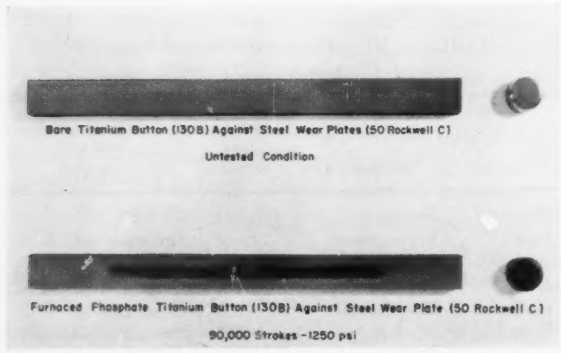
Bare Titanium Button (130B) Against Steel Wear Plates (50 Rockwell C)
Untested Condition
Furnaced Phosphate Titanium Button (130B) Against Steel Wear Plate (50 Rockwell C)
90,000 Strokes - 1250 psi

Figure 3. Appearance of specimens used in studying reciprocating wear

SUMMARY

Three types of conversion coatings have been developed to aid in the lubrication of titanium surfaces: (1) fluoride-phosphate coatings produced by either high- or low-temperature baths, (2) fluoride-phosphate coatings modified by heat treatment, and (3) a sodium hydroxide anodic coating. The regular fluoride-phosphate and anodic coatings may be used to aid in cold-forming operations. The modified fluoride-phosphate coating will probably find more use in continuous wear applications with liquid or bonded solid lubricants. All coatings must be used with a lubricant.

ACKNOWLEDGEMENT

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Machinability or Cutting Fluid Evaluation by Drilling Torque Test

by R. D. Clouse and E. R. Hall***

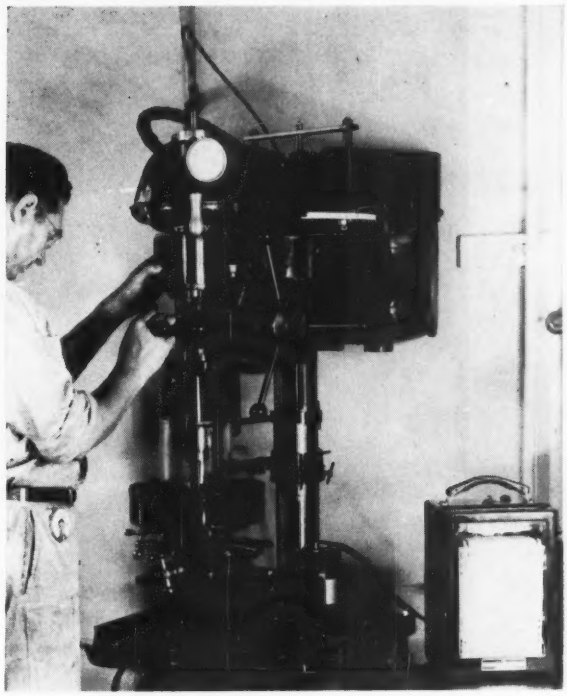

Figure 1. Drilling torque test machine

ABSTRACT

A laboratory power feed drill press has been used to determine the machinability of two new, high-strength stainless steels. As a result of these studies, a technique for evaluating cutting fluids has been developed which yields an optimum tool life rating as well as relative cutting efficiency. Drill press tool life data produced curves that are very similar to those determined from lathe tool life data as expressed by the Taylor equation ($Vt^n = C$). A simplified test method for shop use is provided.

INTRODUCTION

Recently the authors' companies cooperated to determine the machinability ratings, by drilling tests, of two new precipitation hardening steels in a total of eight heat treatments. The effect on drill life of several machining variables (drill feed, drill speed, drill point angle, and drill diameter) was also desired.

When these studies were begun, there was a lack of adequate fabricating information on the new stainless steels, 17–7 PH and AM-350, used by the guided missile industry. General recommendations for cutting speeds and feeds to be used with these steels were available from the steel supplier, but no systematic study of the machining characteristics of the various conditions occurring during heat treatment had been made. The several heat-treated conditions selected for this work represented a wide range of mechanical properties and microstructures. The results of these tests were used to select one of the steels, to determine the heat treatment for its optimum machinability, and to estimate machine tool and manpower requirements.

The results of the drill life versus drill speed tests suggested a method for testing cutting fluids which the small production shop can use. Small shops have a need for a quick and efficient method of evaluating cutting fluids. Most cutting-fluid test equipment requires a large initial investment of time, money, and talent if it is to be suitable for predicting cutting effectiveness under shop conditions. This is especially true of one of the latest developments, the radioactive lathe-tool wear test (1). To a lesser extent, it is also true of the conventional lathe tool life vs. work speed test. Both tests have a place in the research laboratories of large organizations such as machine tool and cutting fluid suppliers. The average shop, however, is unable to support such an effort.

This article will deal with data based on these drilling studies as well as with additional data based on cutting oil tests to explore the utility of a new cutting oil test method. The drill press and drills were common to both test programs.

APPARATUS

An upright drill press was used for all drilling operations. It was equipped with power feed, a wide, continuously variable speed range, and a circulating pump for the cutting fluid. Instrumentation was provided for measuring drilling torque as described in an earlier paper (2). The drill press and torque-measuring systems are shown in Figures 1 and 2.

The drills for each group of tests were all from a single production batch. They were three-eights inch diameter, jobber's length twist drills made from SAE type M-2 high-speed steel.

A single cutting oil and steels of two compositions were used in the drilling studies. The cutting oil was

* California Research Corp., Richmond, Calif.
** Aerojet General Corp., Sacramento, Calif.

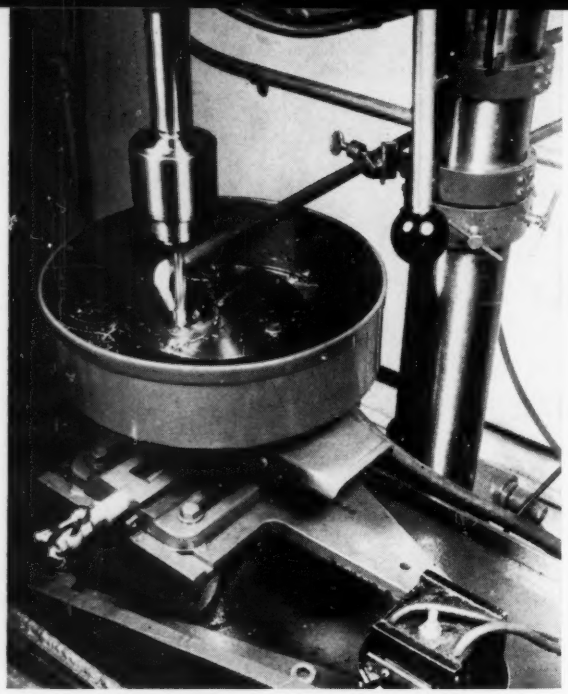

Figure 2. Test block, torque arm, torque ring and electronic pickup

a commercial product containing sulfur, chlorine, and fat. The materials were high-strength stainless steels which can be hardened by the proper combination of annealing and cooling. They are further treated by reheating to the tempering-temperature range. The latter treatment causes hardening by precipitation of an aluminum-nickel intermetallic compound in one of the steels, 17–7 PH. For brevity, the results with the other steel, AM-350, have been omitted. The composition of 17–7 PH steel is given in Table 1; the heat treatments used are described in Table 2.

TABLE 1. CHEMICAL COMPOSITION OF 17–7 PH STAINLESS STEEL

PRINCIPAL ALLOYING ELEMENTS	%
Carbon	0.07
Chromium	17.0
Nickel	7.0
Aluminum	1.10

TABLE 2. HEAT TREATMENT OF 17–7 PH STAINLESS STEEL

HEAT TREATMENT CONDITION	PROCESS
A	Annealed at 1950° F/40 min in hydrogen. Cooled rapidly to room temperature.
R	Annealed at 1750° F/40 min in hydrogen. Cooled rapidly to room temperature. Transformed at—100°F/2 hr.
RH1125	Condition R; aged at 1125°F/2 hr.
T1600	Annealed at 1950°F/40 min in hydrogen. Conditioned at 1600°F/90 min in hydrogen. Transformed at 60°F/1 hr.
TH1250	Condition T1600; aged at 1250°F/90 min.

The cutting oil test was made with two cutting oils and one work material. One of the cutting oils was the same as that used in testing machinability of the materials. The other was a less active oil for less demanding service. It also contains sulfur, chlorine, and fat. The work material was 18–8, Type 304, stainless steel, selected because it is difficult to machine and is in common use.

METHOD

An important part of the method, which is common to both the drilling studies and the cutting oil tests, was the technique for determining drill failure. The technique involved measurement of cutting torque by the aid of suitable instrumentation. A continuous value of cutting torque was recorded. For both tests, a cutting torque of 110 in.-lb was used as a limit beyond which drilling was discontinued. Any drill having reached a torque of this value was said to have failed. Typical torque curves are presented in Figure 3. Representative drill points, used and unused, are shown in Figure 4.

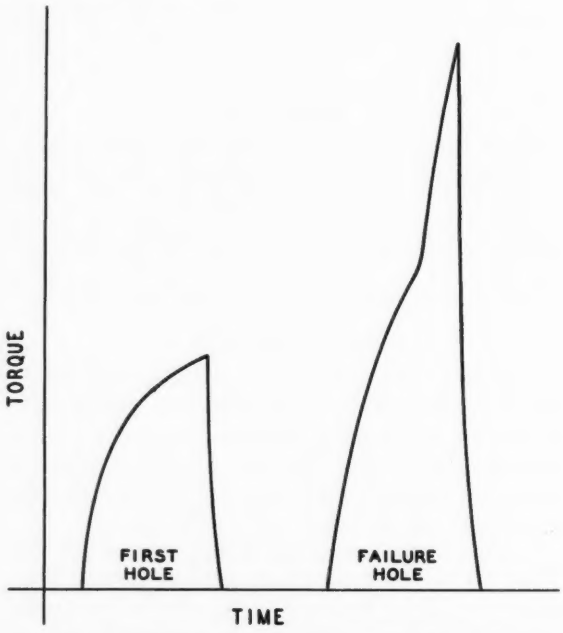

Figure 3. Typical torque curves for normal drilling and at failure

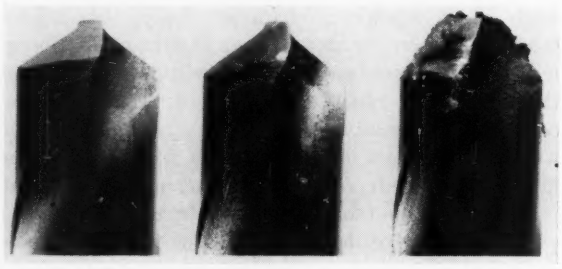

Figure 4. The nature of drill failure
Left: Unused drill
Center: Failed at 110 in. lbs. cutting torque
Right: Failed at 120 in. lbs. cutting torque

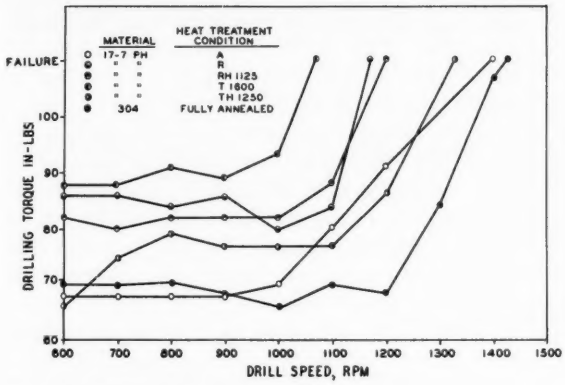

Figure 5. Drilling torque breakdown test
3/8″ dia. high speed twist drills
point angle—130°
Depth of hole—1/2″
Feed—.012″/rev.
Cutting fluid—Cutting oil 210 TA
Three drills per hole

The drilling studies include two tests which are pertinent to this article. One of these was the Drilling Torque Breakdown Test which had the twofold purpose of giving a machinability rating for the materials and establishing a drilling speed for following tests. The test consists of drilling fixed-depth holes into a steel test block at a fixed feed rate and at successively greater speeds with the test drill until it fails.

The other test was the drill life versus drill speed test. This test consists of drilling consecutive holes with a test drill at a fixed feed and speed until the drill fails. Tests are made at enough speeds to define the shape of the curve.

The results of the latter test suggested its use to compare cutting fluid effectiveness. Therefore, a one-drill breakdown test and a drill life versus drill speed test (two drills per speed) were made with each of two oils. The purpose of the one drill breakdown test was to establish an initial speed for the life versus speed test.

Possible variables in drilling tests are drill geometry, drill alignment, hardness of work material, coolant flow rate and placement, and measurement of drill failure. To reduce variables due to drill geometry, each drill is precision ground with the aid of a drill grinding fixture. To ensure drill alignment, a "pilot hole" is used. This is a shallow hole drilled with the test drill at a reduced speed to a depth such that the entire cutting edge is below the surface of the work material. To eliminate possible variations in machinability, hardness traverses are made on the test blocks from each new lot. Variations in hardness reflect differences in microstructure and machinability. Coolant flow should be maintained constant in respect to volume and placement. Variations in the placement of the coolant flow over the drill markedly affect the life of the drill. Special care is taken to ensure that the position of the coolant-delivery tube remains fixed.

DISCUSSION

The results of the Drilling Torque Breakdown Test are presented in Figure 5. This figure illustrates the test method. The relative machinability rating of the steels is correlated to the speeds at which drills failed for each of the test materials. Annealed Type 304 stainless steel, which has a low machinability rating, is the most machinable on this basis.

Typical results of the drill-life versus drill speed tests, made with 17–7 PH steel as work material, are presented in Figure 6. These tests were performed with a single cutting oil. One heat treatment is shown at two feed rates; the other at only one. The plotted points are the average of three drill life values. Excellent straight-line relationship on log-log paper shows the reliability of the test method.

Figure 7 presents results of comparisons of two cutting oils on the basis of drill life versus drill speed tests. Lines of the same slope have been drawn through the results of tests with each oil. One of the oils appears to be 15 times as effective as the other, on the basis of drill life

The same data illustrate the advantage in time and material of running a one-drill breakdown test for each oil. If a drilling speed of 750 rpm had been arbitrarily selected to begin drilling tests, 11 holes would have been drilled with each drill with Oil 1; 150 holes would have been drilled with Oil 2.

The general equation for curves which plot as a

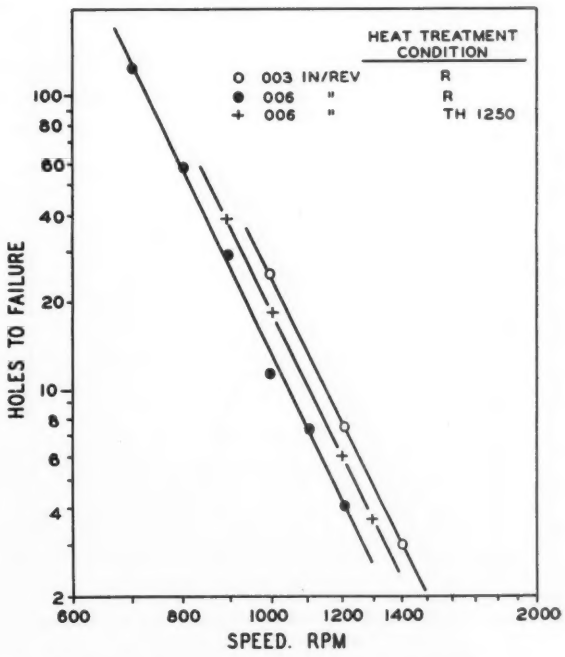

Figure 6. Drill life-drill speed relationship for 17-7PH
3/8″ dia. high speed twist drills
Point angle—130°
Depth of hole—1/2″
Cutting oil—210A

straight line on log-log paper, such as that used to present Figures 6 and 7, may be written $xy^n = C$, where x and y are variables and n and C are constants. The relation between lathe-tool life and turning speed has been shown to be of the same type. For constant feed, depth of cut, cutting fluid, work material, tool material, and tool geometry, the equation $Vt^n = C$ holds. In this equation, V is cutting speed in feet per minute, t is tool life in minutes, $1/n$ is slope of the curve, and C is the cutting speed for tool life of one minute. Data were used from one of the tests of the effect of drill speed on drill life to determine the constants in this equation. For this particular test, the equation is $Vt^{0.13} = 99$. The data may be put in this form by the means shown in Appendix A.

In a paper (3) presented before the American Society of Tool Engineers, Oxford stated that the equation $Vt^n = C$ "seems to hold." In this paper, representative values of n for the drilling and for the lathe-turning operation were listed. The value of n was stated to lie between 0.25 and 0.35 for the drilling operation and 0.10 to 0.15 for turning. Boston (4) has listed the average value of n for all turning operations as 0.14, and Dorison (5) gave the value of n for the turning operation as from 0.095 to 0.13. The value of n for drilling tests discussed herein is within the range of values for normal turning operations.

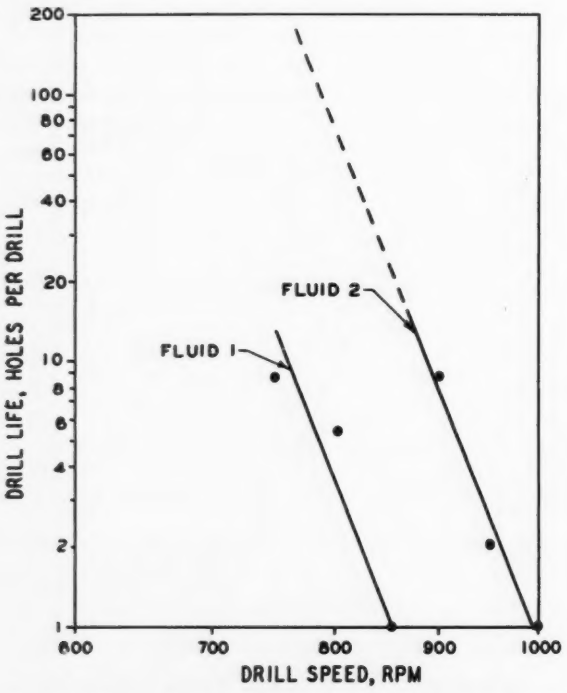

Figure 7. Cutting fluid effectiveness by drill life vs. drill speed
Material—Annealed 304 stainless steel
Drills—118° point angle
3/8″ diameter
Jobbers length, SAE type
M-2 HSS twist drills
Hole depth—1 inch
Feed rate—0.012 in./rev.

The drilling speed for minimum cost has been shown to depend on n and C. For drilling operations in which the equation $Vt^{0.13} = 99$ holds, this speed is expressed as $V_{¢} = 77\ (E/F)^{0.13}$ where E is operating cost of machine and labor in ¢/min and F is the cost of drill change (6). Appendix B shows the manner in which this equation is developed. The similarity of equations and constants strongly suggests that there is a simple coefficient relating drill life to lathe tool life. In this manner, turning speed for minimum cost may be predicted from the results of drilling tests.

An outstanding advantage of drilling tests is the manner in which drill life may be measured. Throughout this series of tests, drill life was specified in terms of a fixed value of drilling torque, established by correlation between drill appearance and torque values (Figure 4). This technique provides the operator with a continuous and clear record of the condition of the drill. Representative drilling torque versus time curves are shown in Figure 3. Measurement of failure by drilling torque may be contrasted with the lathe tool test wherein lathe tool life is determined by inspection with the aid of a microscope.

Although drilling-torque measurements are valuable in determining drill condition, their use is not required. The nature of drill failure is such that the ear can detect the change in the sound of drilling as the failure point approaches.

SIMPLIFIED TEST

The sound and smoke which accompany drill failure can be used to determine drill life; a simplified test procedure can be used by shop personnel to evaluate oils or set up machining conditions.

The new test compares cutting oils on the basis of drill life versus drill speed curves. The required apparatus and method for obtaining the necessary data are listed below.

APPARATUS

1. Any production drill press having power feed and a circulating pump is suitable.
2. Three-eighths inch diameter, high-speed steel twist drills are a convenient size, but they are not mandatory.
3. Uniform work material should be employed. Plate stock generally meets this requirement better than billet stock.

METHOD

1. A one-drill breakdown test is performed by drilling constant depth holes at a fixed feed and at speeds increasing approximately 100 rpm following completion of each hole.
2. A drill life versus drill speed test is performed by drilling constant-depth holes at a fixed feed and speed until the drill fails. Two drills should be used at each speed. Speed steps should be 50 rpm. The first speed should be equal to that at which the drill failed in the breakdown test.

The next speed should be 50 rpm greater. Speeds should be increased in 50 rpm steps until such a speed is reached that a single hole cannot be completed. The next speed should be 50 rpm less than the initial speed. Speeds should be decreased in 50 rpm steps until the curve is defined.

CONCLUSIONS

A. A new technique has been developed for rating cutting oil effectiveness in terms of tool life under metal cutting conditions.

B. The results of this test may be used to predict drilling speeds for minimum cost of production.

C. The tests confirm that the relation between drilling speed and drill life is of the form $Vt^n = C$.

ACKNOWLEDGMENT

Appreciation is extended to Messrs. J. M. Stokely and S. R. Calish of California Research Corporation and Mr. W. E. Moller of Aerojet-General Corporation for their interest and suggestions during this investigation.

APPENDIX A

Determination of Constants in Taylor Equation

To determine the constants in the equation $Vt^n = C$:

$$\text{I. } n = \frac{\log\left(\frac{N_1}{N_2}\right)}{\log\left(\frac{H_2 N_1}{H_1 N_2}\right)}$$

$$\text{II. } C = Vt^n$$

$$\text{where } V = \frac{\pi DN}{12} \quad t = \frac{Hd}{Nf}$$

N is the drilling speed in rpm
H is the drill life in holes at that speed
D is drill diameter in inches
d is hole depth in inches
f is drill feed in inches per drill revolution

For	N_2	V_2	H_2	t_2	N_1	V_1	H_1	t_1
	800	78	58	6	1500	146	1	0.055*

$$n = \frac{\log\left(\frac{1500}{800}\right)}{\log\left[\left(\frac{58}{1}\right)\left(\frac{1500}{800}\right)\right]} = 0.13$$

$$C = (78)(6)^{0.13} = 99$$
$$\rightarrow Vt^{0.13} = 99$$

*Taken from Figure 6 of the text. Heat treatment condition R (Table 2 of the text); feed 0.006 in./rev.

APPENDIX B

Optimum Drilling Speed from Taylor Relationship

With all other machining factors held constant, the cutting speed (in feet per minute) is related to the ensuing tool life (in minutes) by the expression

$$Vt^{0.13} = 99$$

where V is peripheral cutting speed and t is tool life.

Consider the case where the production of a number of pieces involves drilling an identical amount of material from each.

Let A = cost per piece for loading, rapid advance, rapid return and unloading
B = cost per piece for cutting
C = cost per piece for drill replacement whether by redressing or installing a new one
$¢$ = cost per piece for operation

Then $¢ = A + B + C$

A is independent of cutting speed

With E = operating cost rate of machine and labor, ¢/min.
m = volume of metal removed per piece, in.^{3}/piece.
r = drill radius, in.
f = feed increment, in./rev.
V = peripheral cutting speed, ft/min.
F = cost of drill change

$$\text{Then } B = \frac{Em}{6\,rfV} \qquad C = \frac{Fm}{6\,rfVt}$$

$$Vt^n = C'$$

$$¢ = A + \frac{Em}{6\,rfV} + \frac{Fm}{6\,rfC'}\left(\frac{V}{C'}\right)^{\frac{1-n}{n}}$$

For minimum cost $\frac{d¢}{dV} = 0$

$$V_{¢} = \left(\frac{n}{1-n}\right)^n C'\left(\frac{E}{F}\right)^n$$

for $n = 0.13$ and $C' = 99$

$$V_{¢} = 77\left(\frac{E}{F}\right)^{0.13}$$

where $V_{¢}$ = speed resulting in minimum cost.

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ASLE Technical Digest

Papers which, because of space limitations, cannot be published in full in Lubrication Engineering or ASLE Transactons.

"Aqueous Base, Fire Resistant Hydraulic Fluids" by W. H. Millett, Union Carbide Chemicals Co., New York, N. Y.

Fire resistant hydraulic fluids are a practical and realistic solution to the problem of attaining improved safety practices in conventional plant operations. The properties and performance characteristics of the so-called aqueous-base type are of particular interest in view of their wide-spread usage. Basically, these fluids are composed of 35 to 60 percent water to impart nonflammability, a glycol and a water-soluble thickener and lubricant to give the desired body or viscosity. In addition, the resultant product will contain carefully selected additives to fortify the corrosion preventive properties, as well as the anti-wear and lubricity characteristics.

Naturally the industrial consumer is concerned with the scope and significance of the following important characteristics.

1—*Fire resistance,* relates to safety and insurance provisions. As long as the water content is maintained, an aqueous-base fluid is essentially nonflammable. Therefore, continued exposure to elevated temperatures sufficient to cause water evaporation or boiling should not be allowed. Otherwise, residual fluid will burn when ignited.

2—*Viscosity* relates to pumpability according to the requirements of the hydraulic system. It is practicable to adjust viscosity by varying the amount of thickener in the product.

3—*Corrosion protection.* Additives used offset normal corrosion propensity of water.

4—*Effect on seals or packing.* Normally negligible; accordingly conventional materials can be used in hydraulic system makeup.

5—*Wear resistance.* Here again, the additives used are effective. Normally maintenance and replacement of pump parts is not significantly greater than with conventional petroleum oils.

6—*Solvent effect* can be serious when the fluid contacts certain types of conventional paints or coatings. Usual precaution is to remove all paint from interior surfaces of the hydraulic system before charging with an aqueous-base hydraulic fluid, unless it is definitely known that the paint will not be affected.

7—*Vapor pressure.* High at elevated operating temperatures due to water content. Water loss or loss of volatile additives therefore must be considered. The usual maximum suggested service temperature for such fluids is 150° F.

8—*Grease contamination.* Overgreasing can result in accumulation of grease on filters or screens since greases are not soluble or readily dispersible in aqueous-base fluids.

9—*Galvanized* or zinc-coated or cadmium-coated surfaces should be avoided due to soluble effect of such fluids on these metals.

INSTALLATION AND CONTROL IN SERVICE

The extent to which satisfactory performance can be expected from the use of such fluids hinges upon proper installation and thorough cleanliness of the hydraulic system prior to charging. Draining and flushing of the system where such a fluid is to replace one of different characteristics such as a petroleum oil is especially important. While a small amount of residual oil will not materially affect the performance of an aqueous-base fluid, it can detract from the nonflammability feature.

Service control testing is the ultimate measure of the continued suitability of such a fluid, realizing that water evaporation can cause increase in viscosity. Make-up water can be added according to charts and tables available in order to restore viscosity but hard water should *not be used* as it may cause inhibitor or additive precipitation. Control tests normally should be conducted at three or six month intervals according to the operating conditions. (*Digested by A. F. Brewer*)

"Development of New Automotive Gear Lubricants" T. P. Sands, Monsanto Chemical Co., St. Louis, Mo.

Ordnance tests at Yuma, Arizona and San Antonio, Texas indicated a lack of adequate protection in Ordnance equipment operating in heavy duty service under conditions of both high speed and high torque.

Subsequent laboratory and confirmatory field testing resulted in the development of a laboratory endurance type full scale test known as the L-37. Oils passing this test would also adequately lubricate the Ordnance heavy duty equipment.

At about this time the automotive passenger car manufacturers urged the Coordinating Research Council group working on the problem to consider test procedures which show improvement in the anti-scoring or high speed properties of the gear lubricant. The committee could not develop a new scoring test because they did not know how severe the test should be to satisfy the various passenger-axle requirements.

The use of a series of reference lubricants was then proposed as a means of describing the high speed severity level requirements. In this system, the top performance anti-scoring level was arbitrarily designated as Reference Oil 15. This number is followed by a 75, 80, 90 or 140 which designates the viscosity grade of the gear lubricant. The bottom of the Reference scale, a straight mineral oil, is known as 0-90, in the case of the 90 grade oil. By blending Reference Oil 15 and Reference Oil 0 in the proper proportions, intermediate numbers from 0 to 15 can be obtained.

Using this series of reference lubricants it was found that a scoring level of 10-90 is required for field refill of axles to take care of the majority after some break-in on the axles has been accomplished. Accordingly, a laboratory test was developed which would pass Reference Oil 10-90 but fail any oil with less than 10-90 scoring protection.

Since the chemistry involved in these reference fluids represents but one type, the question might be raised as to the degree of correlation of such tests when other types of gear lubricants are employed. This is a legitimate question and steps have been taken to answer the question on the validity of the program. (*Abstracted by the Paper Review Subcommittee of the Gear and Gear Lubricant's Committee, P. A. Asseff, Chrmn.*)

"Chemical Additives for Hypoid Gears" C. V. Smalheer, The Lubrizol Corporation, Cleveland, Ohio.

The trend toward the wider use of chemical additives has been stimulated by advances in engine and gear design which continue to place increasingly se-

vere demands on lubricants. During the last decade important improvements have been made in additives intended for use in hypoid gear lubricants. These improvements have been made largely through the use of full-scale hypoid test equipment.

The chlorine-sulfur type of hypoid lubricant constituted by far the major portion of all gear lubricants sold in the United States through the period ending with the close of World War II and is still sold in substantial quantities throughout the world. In more recent years, phosphorus compounds have also been employed as components of hypoid lubricants.

Towards the close of World War II, the Ordnance Department of the United States Army, drawing both from its wide field experience and from the work of the Coordinating Research Council, issued a new gear lubricant specification which called for two full-scale hypoid gear tests. One test, a high speed axle test, was run under high speed and low torque conditions, and the other, a high torque axle test, was to be run under low speed and high torque conditions. This new specification, which was promptly adopted by the petroleum industry as a criterion for gear lubricants destined for the civilian market as well as for the military, gave a decided impetus to full-scale test research. No bench device or combination of bench devices proved adequate to predict the performance of a lubricant in both of these tests.

Lead soap-active sulfur and chlorine-sulfur hypoid lubricants, while they often gave satisfactory performance in the high speed axle test, invariably failed to pass the severe high torque test which specified operation for 30 hours under a ring gear torque of 32,311 inch-pounds.

The new specification also contained a number of strict requirements relating to characteristics such as thermal stability, permanent oil solubility, non-corrosiveness, sulfur activity, and the like. Requirements of this kind greatly reduce the number of "candidate" additives and thereby further complicate the task of developing a satisfactory lubricant.

In developing a lubricant of this type, a series of high torque tests should serve to segregate additives which are effective in this test. Any of these, upon addition to a satisfactory chlorene-sulfur lubricant, should provide a material giving satisfactory performance in both tests.

Unfortunately, the answer was not quite so simple. The combining of additives of proved effectiveness in the high torque test with existing chlorine-sulfur lubricants produced one or the other of the following situations:

(a) pass the high speed, but not the high torque test; or

(b) pass the high torque, but not the high speed test.

Here then a situation must exist where the individual additives were incompatible in a performance sense; that is, helping in one of the tests but negating or reducing the effectiveness of a companion additive in the remaining test.

In view of this unforeseen roadblock it seemed necessary to collect some fundamental information about full-scale high speed and high torque performance characteristics of a wide variety of additive materials. Using data acquired in these studies, a selection of the most promising "building blocks" for the lubricant could then be made.

The following table (Table III) gives the performance characteristics of a number of families of organic compounds in full-scale test equipment studies. Obviously not all the members of these families could be subjected to test; however, several specific members of each family were tested and form the basis for the conclusions. Having these data it was possible to compound a lubricant passing both high speed and high torque tests. It was also necessary, however, to consider other aspects such as stability and cost in choosing the ultimate formulation.

In the last several years, field tests conducted by the Army at Yuma, Arizona have shown that current MIL-L-2105 lubricants do not perform satisfactorily in heavily loaded military equipment under extremes of high speed and high torque. Intermediate field inspections indicated that the mountain portion of the test is by far the toughest hurdle. Thus the test can be characterized as one of essentially a high torque nature.

Cooperative research among several laboratories led to the development of the CRC-L-37 test which showed a good degree of correlation with the Yuma Field results. Concurrent with these developments, passenger car manufacturers were becoming increasingly aware of the necessity of using a lubricant which would prevent scoring of hypoid gears under sudden load or "shock" conditions such as those realized in the Buick 10-A procedure.

Mindful of the experience described in Table III, work was initiated to develop a hypoid lubricant which would satisfy the requirements of both the CRC-L-37 and Buick 10-A tests. The initial approach was one of finding a combination of "compatible performance" additives (helpful in high torque and weak though not harmful in shock service) which would pass the L-37 test. When such a combination "X" was found, its concentration in the lubricant was progressively built up to a level which would provide adequate shock performance. This approach failed since it provided only borderline shock performance at such a high additive concentration as to be economically unsound.

The second approach was to take combination "X" and reinforce its shock properties by the addition of a separate additive effective in that type of service. The larger portion of these additives proved to be of the incompatible performance variety resulting in L-37 test failures.

A limited number of effective shock service additives were found, however, which had relatively little adverse effect in high torque service. It should be noted that throughout this test work, the choice of additives was restricted by considerations of thermal stability, sulfur activity, non-corrosiveness, etc. An example of such a satisfactory lubricant is designated as "Y".

Lubricants comparable to "Y" have

FIGURE III

Key: + = definitely effective
(+) = slightly effective
° = ineffective, but not harmful
(−) = slightly harmful
− = definitely harmful

Family of compounds	Use in hypoid gear service under conditions of: High speed	High torque
Chlorine bearing	+	0 to (+)
Active sulfur in non-carboxylic compound	+	−
Relatively inactive sulfur in non-carboxylic compound	+	(−)
" " " " carboxylic ester	(−) to (+)	+
" " " " carboxylic acid	+	+
Carboxylic esters	−	+
Carboxylic acids	(−) to −	+
Oxyphosphite acid esters	+	+
Oxyphosphite neutral esters	0	0
Oxyphosphate neutral esters	0	0
Thiophosphate neutral esters	+	+

now been used commercially for many months and have established an excellent performance record. Their performance characteristics have also been proven by the Military in further testing at Yuma, Arizona. (*Abstracted by the Paper Review Subcommittee of the Gear and Gear Lubricant's Committee, P. A. Asseff, Chrmn.*)

"New Developments in Gear Lubricants" C. M. Heinen, Chrysler Corp., Detroit, Mich.

Four questions occur in connection with new developments in gear lubricants.

1. What are the changes in requirements for lubrication which have brought about the increased activity in this area?
2. How have these new requirements affected the problem of field application?
3. What new testing techniques are being developed which will help define the new requirements?
4. Will new lubricant formulations be adequate in all respects?

FUNDAMENTAL REQUIREMENTS

Factors tending to promote increase in "scoring."

(a) The fact of higher loads, possibly at higher speeds due to increase in average horsepower.

(b) Increase in car height with trend towards smaller gears and greater offsets in rear axle. Less cooling of gears due to lower silhouettes.

(c) Increased gear loads due to increase of inertia during acceleration and deceleration associated with net increase in car weight.

The only trend in the direction of less scoring is associated with the lower axle ratios which have come about.

FIELD APPLICATION PROBLEMS

In general, lubricants which will give an anti-weld coating are required, with emphasis on the proper degree of chemical activity. An excessive chemical activity results in high rates of wear which are detrimental to gear operations.

Although there is some indication of high wear in passenger cars as a result of the use of high activity lubricants, the condition of high load which results in high wear is encountered most frequently in trucks.

It has also become apparent that universal or multi-purpose gear oils do not have enough chemical activity to supply the necessary chemical films under all the new peak torque conditions. Several solutions have been tried to supplement the film. These include (1) operation for a short period of time with active sulfur lubricant followed by replacement with multi-purpose gear oil (2) forming a phosphate film on the gears during production and using Multi-purpose gear oil and (3) recommending active sulfur lubricant for the life of the car.

It is the third recommendation which causes the most trouble from a merchandising point of view. Since an active sulfur lubricant is not satisfactory for truck operation and since many of the trucks on the road come to service stations for lubrication, two lubricants would have to be carried. This results in considerable confusion and the fear of probable confusion has led seven manufacturers representing 70% of the industry production to ask that "no change" be made from the passenger car factory fill. These recommendations have been reinforced by the removal of the drain plug.

One way of avoiding confusion and returning to normal drain period recommendations is to develop a truly multi-purpose gear lubricant. This accomplishment hinges on the development of tests which adequately define a suitable level of protection.

TEST DEVELOPMENTS

The logical place to start is to use the military specification oils as a base line. In addition to this, the Ordnance group has indicated a strong desire to have the military specification conform to what was available in the civilian market so as to simplify the supply problem in the case of an emergency.

With this approach in mind, the problem falls logically into three phases:

1. Determining what level of performance the present tests were defining in some absolute terms.
2. Establishing several ranges of test severity which would describe all existing oils and allow a range for oil improvements.
3. Finding where in the range of test severity an oil must fall to meet present requirements.

Work on each of the steps is underway and a status report is given on each phase.

LUBRICANT FORMULATIONS

Recent tests at Yuma indicate that the question of chemical corrosion may once more be of importance. Although some improvements in the deposit tendency of oils have occurred, the increase in axle temperatures mean that this tendency will have to be watched closely. Other than this, the problem of introduction of these oils seems more economic than technical. (*Abstracted by the Paper Review Subcommittee of the Gear and Gear Lubricant's Committee, P. A. Asseff, Chrmn.*)

Note: Unabridged copies of the foregoing papers are not available at Society headquarters. Those wishing additional information about these papers should contact the author.

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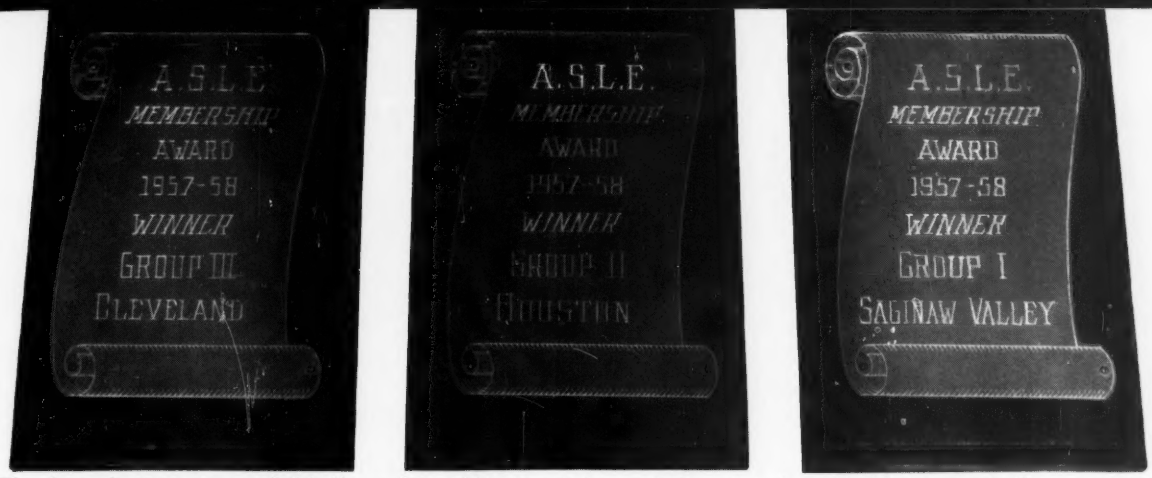

The above plaques were awarded to the sections which showed the greatest percent of membership increase in the year 1957-58.

Section News *(Cont. from page 455)*

and Clyde Harrison and Norbert Zimmerman of American Brass Co. . . . **Montreal**—October 1 meeting featured King Simpson of Electro-Motive Div., General Motors Corp., speaking on "Diesel Electric Locomotive Lubrication." "The Bull about Bull Gears" was Gordon Irving's topic at November 5 meeting. December 3 meeting will highlight S. C. M. Ambler's talk on "Crude Oils." . . . **New York**—An automotive lubrication panel played to 85 listeners at September 17 dinner meeting. Moderator was C. W. Nichols, Socony Mobil Oil Co. Speakers were G. H. Link, Shell Oil Co., O. W. Wuerz, Cab Service Parts Corp., and C. L. Knapp, Esso Research and Engineering. October 22 meeting included social hour, cocktails sponsored by Acheson Colloids Co., Alpha Molykote Corp., Climax Molybdenum Co. and Joseph Dixon Crucible Co. Meeting featured a panel of four specialists on solid lubricants, moderated by E. E. Smith, manager of chemical sales at Climax Molybdenum Co. Speakers were: S. B. Seeley, Dixon Crucible, A. Lewis, Alpha Molykote, Mrs. F. A. Popejoy, Allen Lubricants, and W. C. Kiefer, Bel Ray Co. . . . **Ontario**—J. B. Benskin of Lincoln Engineering Co. presented paper on "Dispensing, Handling and Storage of Lubricants" at September 9 inaugural meeting. A discussion of "Soluble Cutting Oils" by S. C. Zylstra, D. A. Stuart Oil Co. Ltd., was presented at October 14 meeting. . . . **Pittsburgh**—September 11 business meeting was followed by Don W. Gow's paper on "Effect of Oil Change Interval on Low Temperature Wear and Deposit Forming Characteristic of Crankcase Oils." Lively question and answer session followed. . . . **Rochester**—Thomas L. Brennan presented talk on "Lubrication and Design of Bearings" after October 8 smorgasbord dinner. . . . **Saginaw Valley**—Members present at October 30 meeting heard Frank Sargent, National Refining Co., speak on "Fundamentals of Lubrication." Machine Tool Lubrication Course co-sponsored by Mott Foundation began October 20, meetings for six consecutive Monday evenings at Flint Junior College. . . . **Syracuse**—After October 20 cocktail hour (sponsored by Commercial Filters Co.) and buffet dinner, H. A. Wilson spoke on "Filteration as Applied to Petroleum Products. September 15 meeting was held jointly with Plant Engineers' Society of Syracuse—John Carl, Crouse-Hinds Co., discussed "Systematic Record Keeping for Preventive Maintenance of Machine Tools." . . . **Twin Cities**—Twenty-one members and 35 guests, many from the Chicago and Milwaukee Sections, heard Hugh L. Hemmingway, Pure Oil Co., explain that "Oils Do Wear Out." October 30 joint meeting with Duluth Section featured discussion of "Lubrication of Paper Plant Machinery" by Bruce Dunham, Sun Oil Co. Tours of paper companies were held on October 31.

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Automation in Lubrication

(Cont. from page 472)

The capital investment on machine (B) was $43,642. The central systems of this machine raised the initial cost by 2.87 per cent. The labor cost added an additional 1.42 per cent to the machine cost or the combined lubricating equipment and installation cost of 4.20 per cent was added to the investment.

Machine (C) required a capital expenditure of $32,962. The lubricating equipment increased this initial cost by 3.22 per cent while the labor added an additional .51 per cent to the capital investment, The combined lubricating equipment and installation cost amounted to 3.73 per cent additional expenditure.

By comparing machines A-B-C alone, one can see the wide variation in cost of central automatic lubricating systems; yet all three installations are less than 5 per cent of the initial capital expenditure.

A 5 per cent increase in capital expenditures for proper lubricating equipment will more than offset the delays in production caused by improper lubrication and mill lubrication delays.

SUMMARY

Capital equipment equipped with automatic central lubrication systems will accumulate records of continuous service, extended periods between delays in down time of capital equipment and will definitely prove the economic aspects of automatic lubrication.

Management must become more aware of the advantages of automatic lubrication in order to be impressed. Therefore, an informed management will make progress in a plant-wide lubrication program.

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CORRECTION

In the paper, "Measuring Activity of Sulfur Additives in Oils" by Helen Sellei, published in the October issue, two words were omitted in error. On page 435, under MEASURING COPPER CORROSION, the test tube is stoppered with a *vented* cork. On page 438, below the figure, the curves at longer times asympotically approach the amount of *active* sulfur present.

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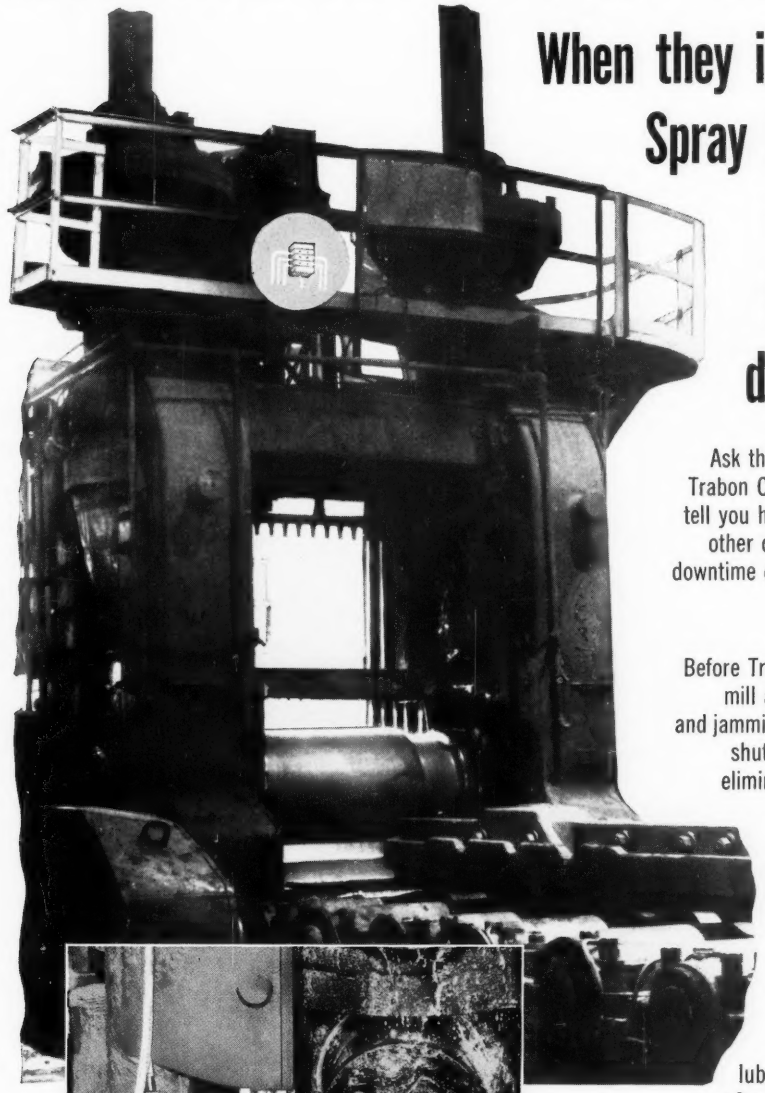
☐ 58LC-14. "Effect of Fibre Orientation, Temperature and Dry Powder Lubricants on Rolling Contact Fatigue," by W. J. Anderson and T. L. Carter

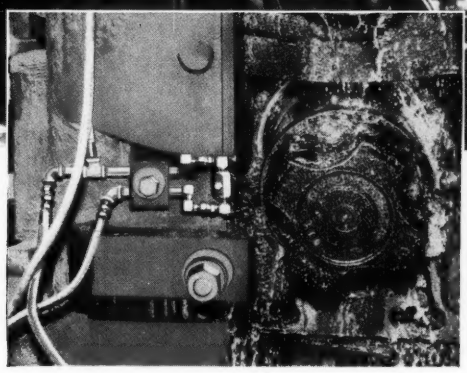
☐ 58LC-15. "Rolling Contact Fatigue Evaluation of Bearing Materials and Lubricants," by E. G. Jackson

☐ 58LC-16. "Materials in Rolling Element Bearings for Normal and Elevated (450°F) Temperatures," by T. W. Morrison, H. O. Walp, and R. P. Remorenko

TRABON

CENTRALIZED LUBRICATING SYSTEMS





Insets show a Trabon feeder and two spray nozzles protecting roll neck bearings on a 40″ mill. Despite heat, water and dirt, Trabon delivers an exact, metered amount of lubricant to all bearings automatically.

When they installed a Trabon Spray System here... they saved several hundred thousand dollars in six years

Ask the men who operate this 40″ mill about Trabon Centralized Lubricating Systems! They'll tell you how a Trabon spray system, along with other changes, saved five expensive hours of downtime **every** week. How increased production time **alone** ran savings to many thousands of dollars the first year.

Before Trabon, critical roll neck bearings in this mill at an Ohio steel plant were burning up and jamming the rolls. Once Trabon was installed, shutdowns due to lubrication failures were eliminated. Bearing life more than doubled. Lubricant consumption dropped from 20 drums to 3 drums a week. For the six years Trabon has been protecting these bearings, savings in production time alone have totaled several hundred thousand dollars.

The Trabon automatic system is connected to an air pressure supply which is in constant operation. Spray lubricant is delivered for **20 seconds out of every minute** with just the right amount of fluid grease needed by the four roll neck bearings. Lubrication is dependable and positive!

You'll find this savings story repeated in **any mill** equipped with Trabon Systems. Why not get technical data by writing today!

Trabon

Trabon Engineering Corporation

28787 Aurora Road • Solon, Ohio

Centralized OIL AND GREASE SYSTEMS *Modufo* CIRCULATING OIL SYSTEMS

Lubrichanics by Hodson

Lubrichanics by Hodson

Tradition Is One Thing
Performance Another

Use "Four Horsemen" Products
For Prime Demands

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